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KENAI RIVER SOCKEYE SALMON SMOLT STUDIES, 1993

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ABSTRACT

Inclined plane traps were placed in the Kenai River to capture seaward migrating sockeye salmon *Oncorhynchus nerka* smolt. Only 3,200 sockeye smolt were captured, continuing a trend of decreasing total annual catches since the first year of the study, 1989, when 161,000 smolt were captured. Historic trap efficiency data were used to calculate a 1993 seaward migration estimate of approximately 486,000 smolt. The minimum migration, including Moose River and Hidden Creek smolt which were not sampled by our traps, was 833,000 smolt. Approximately 88.5% of the population was age-1. smolt and the remainder smolt were age-2. (3.0%) and -0. (8.5%). Coho and sockeye salmon smolt length frequency data revealed decreased trap efficiency with increased smolt size. Age-0. smolt were not thought to be of Skilak Lake origin.

KEY WORDS: Sockeye salmon smolt, *Oncorhynchus nerka*, biological sampling, migratory timing, bismark brown dye, mark-recapture, population estimation, length frequency distribution

INTRODUCTION

The Kenai River (Figure 1) typically contributes more than 50% to annual Upper Cook Inlet (UCI) commercial harvests of sockeye salmon *Oncorhynchus nerka* (Ruesch and Fox 1993). Forecasting the return of this stock is important to the successful management of the fishery. Until 1993, forecasting was based on a combination of adult spawning escapements, age specific maturity schedules, and average numbers of returning adults per spawner. The 1993 forecast included adult sockeye salmon run estimates projected from the number and age composition of sockeye salmon smolt migrating out of the Kenai River.

The Kenai River smolt project has provided an estimate of the number and age composition of sockeye salmon smolt migrating out of the drainage since 1989 (King et al. 1990, 1991, 1994) This information has been used to evaluate sockeye salmon production in the Kenai River drainage in conjunction with estimates of spawners (Davis et al. 1993), juveniles rearing in Kenai and Skilak lakes (Tarbox and Brannian 1993), and adults passing weirs across Hidden Creek (Fandrei 1993) and Russian River (Marsh 1993a, 1993b) tributaries. Comparable production studies are being done in the Kasilof River drainage, the second largest producer of sockeye salmon in UCI (Kyle 1992).

Commercial fishing closures in UCI due to the 1989 Exxon Valdez oil spill resulted in an extremely large spawning escapement into the Kenai River. A suite of projects was designed to evaluate the effects of large spawning escapements on resulting progeny and lake rearing habitat. The Kenai River smolt project was a component of Natural Resource Damage Assessment Project No. 27, *"Sockeye Salmon Overescapement"*, from 1990 to 1992 (Schmidt and Tarbox 1991, 1992).

Objectives of the 1993 Kenai River smolt project were to:

1. estimate the number of sockeye salmon smolt migrating seaward during the peak migration period from 15 May through 30 June;
2. determine the age composition, mean weight, and mean length of sockeye salmon smolt;
3. describe daily and seasonal migration timing of sockeye salmon smolt;
4. determine the number of sockeye salmon smolt migrating adjacent to the right bank; and
5. assess the feasibility of using inclined plane traps to enumerate sockeye salmon smolt migrating from Russian River.

METHODS

Fishing Methods

All traps were similar in design to those used to estimate smolt migrations from the Crescent and Kasilof Rivers of UCI (Kyle 1983). Each trap was 2.1 m long, 1.5 m wide, and tapered in height from 1.05 m at the mouth to 0.1 m at the outlet or downstream end. Trap frames were constructed of angle aluminum and the bottom covered with perforated aluminum plate with 13 mm holes. The sides and top were covered with vexar plastic netting with 13 mm square mesh. The outlet end emptied into a 1.5 x 1.1 x 0.6 m live box which contained one vertical baffle. The mouth and outlet ends of the trap could be adjusted vertically to control fishing depth and the amount of water which entered the live box. Traps typically fished to approximately 1.0 m below the surface. All traps were fished continuously throughout the study. Traps were monitored continuously and emptied at least twice between 0001 h and 0500 h. Traps were checked only sporadically through the remainder of the day, and generally emptied once more between 2200 and 2300 h. All captured juvenile salmonids were counted and recorded by species and stage of development.

Kenai River

Six stationary floating inclined plane traps were placed in the Kenai River approximately 31 km upriver from the mouth (Figure 2). The river was 105 m wide with a maximum water depth of 2.5 m at the km 31 trap location (Figure 3). The thalweg occurred 25-30 m from the left bank and both current velocity and water depth generally decreased as one moved toward the right bank. Four of the six traps at km 31 were anchored from the left (south) bank with steel cable, and held at 9, 15, 21, and 24 m from shore with tubular aluminum booms. The inshore trap was designated trap 1. Traps on the left side of the river were placed in the area of highest surface water velocities and greatest flow volume, since we thought most smolt would travel downriver through this area (Hoar 1954, Foerster 1968, Bue et al. 1988). The remaining two traps, designated traps 5 and 6, were initially held 30 m offshore of the right bank using a similar cable and boom arrangement. On June 19 the right bank traps were moved closer to shore because increasing water velocity and debris load precluded continued deployment in the original location.

An additional two traps were placed in the river adjacent to the left bank at km 35. The two traps were anchored and held offshore 6 m and 12 m using cables and booms.

Russian River

A single smolt trap was placed in the Russian River 200 m above the confluence with the Kenai River. The front of the trap was anchored to the river bottom with steel stakes and cabled to shore. The rear of the trap was suspended between the legs of a quadrapod. The quadrapod was outfitted with a cable winch to raise and lower the outlet end of the trap. This controlled the flow of water entering the live box.

The trap was centered approximately 6 m from the right bank (Figure 4). Weir panels extended from the front of the trap, increasing the opening width to approximately 4 m. The near shore panel was 4 m long and ended 4 m from the left bank. The off shore panel was 8 m long and ended 9 m from the left bank.

The Russian River was 28 m wide at the front end of the trap weir panels (Figure 4). The maximum water depth of 0.54 m occurred 6 m from the right bank. Water depth decreased erratically to the left bank.

Estimating Smolt Abundance

Estimating Trap Efficiency

Methods used to estimate trap efficiency were similar at the Kenai River km 31 and Russian River sites. Sockeye salmon smolt were dyed and released each day until a minimum sample size was attained. No new releases of dyed smolt were made during the next 48 hours to allow those released to pass the counting site. This provided trap efficiency data within time strata. Sample size for each stratum was 2800 dyed sockeye salmon smolt for the Kenai River and 500 dyed sockeye salmon smolt for the Russian River.

The km 35 site was established as a dye site only. By dyeing 2800 sockeye salmon smolt at this site, we hoped to preclude dyeing at the km 31 site and allow the crew there to focus on examining fish for dye. We also suspected that we were subjecting fish to additional stress at the km 31 site by first examining them for dye and then using the same fish for dyeing.

At the km 35 site, sockeye salmon smolt were dyed in a solution of 5 g Bismark Brown in 190 l of water (approximately 1:36,000) for twenty minutes. Dyeing was done in the morning, using the previous night's catch. As sockeye salmon smolt were removed from the trap, they were counted and immediately placed into a live tank mounted in a boat. The water in this tank was constantly replaced by fresh river water using a battery operated pump. Smolt were dyed, held in the live tank for at least 12 hours, and released at approximately 2200-2300 h. After live smolt were released, dead smolt were counted to determine percent mortality from handling and dyeing. All smolt captured in the km 31 traps in the next 48 hours were examined for evidence of dye.

Russian River sockeye salmon smolt were dyed for 60 minutes in a 1:75,000 solution of neutral red. We used neutral red at this site to avoid including smolt dyed at the Russian River with dyed smolt recovered in the km 31 traps. Oxygen was pumped into the tank throughout the dyeing procedure. After 60 minutes in the dye, smolt were placed in perforated containers in the river and held until approximately 0500 h. Dyed smolt were then transported in buckets to a live box located approximately 0.8 km upstream of the trap for release the next evening at approximately 2200 h. Prior to release, we removed and counted any weak or dead smolt. We assumed that since dyed smolt were released in mid-stream at the onset of the nightly smolt migration, there would be adequate mixing of dyed smolt and other migrating sockeye salmon smolt prior to arrival at the trap. All smolt captured in the trap were examined for evidence of dye.

The number of smolt dyed and released (M_i) each marking period at the km 35 site was set at 2,800 to obtain an estimate of abundance (N_i) with a relative error of +/- 25% for trap efficiencies equal to or greater than 2%. Trap efficiency was defined as the number of recaptures (r_i) divided by the number of smolt dyed and released. Required M_i for a given trap efficiency varied only slightly with number of smolt caught ($\hat{C}_i$), but increased dramatically with decreasing trap efficiency. A 2% trap efficiency was twice that seen in previous years, but sample size requirements for lower efficiencies would require handling more smolt than we thought we could capture and process. We also assumed that dye marking events could be pooled since trap efficiencies of adjacent time strata were not significantly different in 1989 and 1990 (χ^2-test with $\alpha=0.05$ critical level). Pooling just two adjacent strata would result in a sample size of 5,600 smolt, which would provide estimates with the desired relative error for trap efficiencies as low as 1%.

At the Russian River site, we thought that the trap efficiency could reach 15%. We therefore selected a minimum sample size of 500 sockeye smolt for each stratum. This would give a relative error of +/- 25% for the estimate even if trap efficiency was as low as 10%.

Our estimator, like other mark-recapture estimates of population size, was biased when low numbers of dyed sockeye salmon smolt were recaptured (Seber 1982). To keep the level of bias below 10%, enough smolt had to be marked to ensure that at least 10 dyed smolt were recaptured within each time stratum. Fewer recaptures would result in a positive bias which would increase rapidly as recaptures fell below 10 smolt (King et al. 1994).

Analyses assumed: (1) all released dyed sockeye salmon smolt moved past the trap site within 48 hours so dyed smolt from one time period would not be caught in another; (2) the probability of capture among traps at km 31 was the same for marked and unmarked smolt; (3) the probability of capture for each individual smolt was independent of that of other smolt.

Estimating Sockeye Salmon Smolt Abundance

Sockeye salmon smolt abundance ($\hat{N}_i$) was estimated from trap data collected at km 31 (traps 1 through 4 only) using LaPlace's ratio estimate (Cochran 1978) as adapted by Rawson (1984):

$$\hat{N}_i = \hat{C}_i \frac{M_i}{r_i}[1+\frac{M_i-r_i}{M_i r_i}] \quad , \qquad (1)$$

where:

$\hat{N}_i$ = number of undyed sockeye salmon smolt migrating past traps in period i
$\hat{C}_i$ = number of sockeye salmon smolt caught in traps in period i
M_i = number of sockeye salmon smolt dyed and released upstream in period i
r_i = number of dyed sockeye salmon smolt recaptured in traps in period i.

The variance of $\hat{N}_i$ was estimated as:

$$V(\hat{N}_i) = \hat{C}_i(\hat{C}_i+r_i)M_i\frac{(M_i-r_i)}{r_i^3} \quad , \tag{2}$$

and the (1-α) confidence interval as:

$$\hat{N}_i \pm z_\alpha\sqrt{V(\hat{N})} \quad , \tag{3}$$

where z_α = the (1-α)/2 percentage point of the standard normal distribution.

Sockeye salmon smolt abundance in 1993 was also estimated with a resampling technique (Effron 1982) based on the number of smolt dyed and recovered each spring from 1989 through 1993. Data from each year were pooled when trap efficiencies were not significantly different (χ^2 test, $p=0.05$) between time strata. Data for the entire season were pooled for 1989, 1991, 1992 and 1993, but had to be split into two strata for 1990. These six pairs of M_i and r_i values were randomly chosen with replacement to produce estimates of 1993 smolt abundance using equation 1. The mean of five hundred bootstrap replications was used to estimate smolt abundance in 1993 (N_{93}):

$$N_{93} = \frac{\sum_{b=1}^{500} N_b}{500}, \tag{4}$$

Variance of N_{93} was then calculated as:

$$V(N_{92}) = \frac{\sum_{b=1}^{500} (N_b - N_{92})^2}{500-1} \quad . \tag{5}$$

A 95% confidence interval was approximated by ranking 500 estimates in ascending order and then using the 13th largest estimate (2.5 percentile) as the lower bound, and the 486th largest estimate (97.6 percentile) as the upper bound.

Run Timing

Migration timing was based on the proportion of the total catch made each day. We assumed that most smolt migrating from the Kenai River system passed the trap sites during the operational period. Therefore the mean date of the migration was the date when 50% of the total catch had occurred at the trap sites.

Age, Weight, and Length Sampling

Sockeye salmon smolt captured in km 31 and Russian River traps were sampled for age, weight, and length (AWL) information. A scale smear from the preferred area (INPFC 1963) of each smolt was placed on a standard laboratory slide for age determination, and each smolt was weighed to the nearest 0.1 g and measured (fork length) to the nearest mm.

Because of low catches at both the km 31 and Russian River sites, desired sample sizes were not obtained for the any of the 5 day time strata originally set for AWL sampling. However, nearly all smolt not used for the mark-recapture experiment were sampled for AWL information. Sample periods were initially redefined as the number of days needed to collect at least 300 smolt. This sample size provides a binomial (two age classes) simultaneous 90% confidence interval of +/- 0.05 when the proportion of the major age class in the population is at least 0.75. No samples were taken at the km 31 site from 1 to 9 June, the period when most of the smolt migrated from the system, since all available smolt were dyed for trap efficiency tests. We also could not use the next 300 smolt sample to estimate the age composition of the early June migration. This sample was not representative of the early portion of the migration since half of the sample was obtained later in June when age-0. smolt were most abundant. Consequently, we divided this 300 smolt sample into two periods and used only smolt captured during 10-12 June to represent the migration during 1-15 June.

AWL data were also collected from sockeye salmon smolt migrating from Moose River and Hidden Creek. We compared age composition, mean length and length frequencies for smolt from these tributaries to values from samples collected at the km 31 site to determine whether these substocks were represented in the km 31 trap catches. Age-specific mean lengths were compared among smolt samples from km 31, Moose River, Hidden Creek, and Russian River sites using one-way ANOVA to determine whether differences could be detected. Contrast statements were used to determine which sites were different. All tests were conducted at the nominal $P \leq .05$ level of significance. The same analyses were performed on mean lengths for age-0. smolt captured in the km 31 traps, 1992 age-0. fall fry captured in Skilak Lake, and 1993 age-0. summer fry captured in Skilak Lake.

We also examined length data from adipose fin clipped coho salmon smolt captured in the km 31 traps to provide another measure of trap efficiency. These marked coho salmon smolt were captured in the Moose River and marked by inserting a coded wire tag into the snout and removing the adipose fin (Carlon and Hasbrouck 1993). Nearly all coho salmon smolt passing the weir were tagged except a random sample preserved daily for collection of AWL passing the weir were tagged except a random sample preserved daily for collection of AWL data. We assumed that the length frequency distribution of the AWL sample (n = 1,217) accurately represented the distribution for marked migrants. We were therefore able to apportion the total Moose River coho salmon smolt migration and the total km 31 catch of marked coho salmon smolt into 5 mm length interval strata. We then calculated a trap efficiency for each length stratum.

Climatological and Hydrological Sampling

Water velocity (m/sec) measurements were taken at the surface in front of each km 31 trap whenever river depth rose or fell 0.3 m. Water depth (m), temperature (°C), and turbidity (maximum depth in m a secchi disc was visible) were measured daily at this site. Kenai River daily discharge was calculated from stage height data gathered at river km 34 by the Alaska River Forecast Center (L. Rundquist, National Weather Service, NOAA, Anchorage, pers. comm.).

RESULTS

Km 31 site

Traps were fished from 17 May until 5 July 1993 at the km 31 site. Although we were prepared to subsample catches (King et al. 1991), the seaward migration was small enough to allow us to identify and count all fish captured.

A total of 105,229 fish were captured in traps 1-4 (Tables 1 through 5). Three percent (3,200) of the total fish caught were sockeye salmon smolt. Captures of fry of all salmonid species exceeded those recorded in previous years (Table 6). The historical trend of increased numbers of smolt and decreased numbers of fry with distance from shore of all species continued. Sockeye salmon smolt captures have decreased each year since the inception of the project in 1989 (Table 7).

Traps 5 and 6 caught a combined total of 14,357 fish of which 670, or 4.7% were sockeye salmon smolt (Tables 8-10). Most of the catch consisted of sockeye fry (36.7%), pink fry (20.9%), chinook fry (15.1%) and coho fry (10.8%). Catches of fry, except pink salmon, were proportionally higher than traps 1-4 combined, and the proportions of each group were most similar to traps 1 and 2. Sockeye salmon smolt catches from traps 5 and 6 represented 17% of the total catch of all traps, roughly half of that expected if smolt were uniformly distributed in the river. One dyed sockeye salmon smolt was captured in trap 6 on 5 June. Over 75% of trap 5 and 6 sockeye salmon smolt captures occurred prior to moving the traps closer to shore on June 19. Approximately the same percentage of the catch of sockeye salmon smolt in traps 1-4 also occurred prior to that date.

A total of 1,934 sockeye salmon smolt were dyed and released upstream. Survival during the holding period between dyeing and release ranged from 0.905 to 0.969 and averaged 0.926 (Table 11). The high survival rate reflected changes in procedures instituted in 1992 to reduce handling stress (King et al. 1994).

Six of the dyed sockeye salmon smolt released were recaptured in traps 1 through 4, resulting in a total trap efficiency of 0.003. This compares with trap efficiencies for the years 1989 through 1992 of 0.007 to 0.021 (Table 12). The ratio of dyed to undyed smolt was the same among traps 1 through 4 ($\chi^2=3.38$, $p=0.337$, 3 df). Using the 1993 M_i and r_i values resulted in an estimate of migration of 1,202,844 sockeye salmon smolt.

We chose to use the six pairs of M_i and r_i values from 1989-93 to generate 500 bootstrap estimates for 1993. The mean of 486,181 sockeye salmon smolt (Table 13) was used to estimate the 1993 smolt population. The 95% confidence bounds ranged from 163,998 to 1,202,844 smolt.

Sixty-three percent of the measured sockeye salmon smolt seaward migration occurred between 1 and 8 June, although within that time frame there were three distinct peaks in the daily passage rate (Figure 5). Only 1.0% of the migration occurred within the first 8 days of counting, and a relatively steady daily migration which constituted 20% of the total occurred during the last two weeks of the project. Age-2 sockeye smolt left the drainage earlier than age-1 smolt (Table 14).

An estimated 88.5% of the sockeye salmon smolt sampled at the km 31 site were age 1. (Table 15). There was a significant ($\chi^2=37.06$, $p=0.05$, 1 df) decrease in the proportion of age-2. smolt in period 2. In addition, there was a significant ($\chi^2=99.07$, $p=0.05$, 1df) decrease in age-1. and increase in age-0. migrants in period 3.

Age-0. sockeye salmon smolt, which comprised 8.5% of the estimated migration, have not been captured in the traps in previous years. These smolt were first captured on 19 June. The mean length for the first time stratum after their initial appearance was 51 mm (Table 16). Analysis of variance indicated that the mean length of the age-0. smolt captured at km 31 was smaller ($P<0.0001$) than that of the 1992 fall fry captured from Skilak Lake (Tarbox and Brannian 1993). Conversely, ANOVA revealed that the 1993 age-0. smolt were longer ($P<0.0001$) than 1993 age-0. fry sampled in July in Skilak Lake (mean = 41 mm; K. Tarbox, ADF&G, Soldotna, pers comm.).

As in 1992, mean lengths and weights of sockeye salmon smolt were greater than in any of the previous years (Table 16; Figures 6 and 7). In 1993 the mean length of age-1. sockeye salmon smolt from the km 31 (mainstem) traps and from samples collected in the Moose, Hidden, and Russian tributaries were, respectively, 77.9 mm, 114.2 mm, 130.1 mm, and 80.9 mm. The mean length of the km 31 age-1. smolt was significantly less than each of the substocks ($P<001$ in all cases). Mean length of age-2. sockeye smolt from the km 31 traps and from samples collected in Hidden, and Russian tributaries were, respectively, 98.2 mm, 187.4 mm, and 93.7 mm. The mean length of km 31 age-2. smolt was significantly different than Hidden Creek $p<0.001$), and Russian River ($p=0.008$) substocks.

In general, Hidden Creek sockeye salmon smolt appeared to be missing from the km 31 trap catches (Figure 8). There was some overlap in the length frequency distribution of km 31 and Moose River age-2. smolt, and the length frequency distributions of age-1. and -2. sockeye salmon smolt captured in the Russian River were very similar to that for the km 31 trap captures. Weighting the length frequency distributions by estimated smolt abundance from each of the tributaries and km 31 again showed that Hidden Creek age-1. smolt were not captured by the mainstem traps, and that Moose River age-2. sockeye smolt were partially available to the gear (Figure 9). Inclined plane traps at km 31 probably also missed most of the age-2. smolt exiting the Russian River. Conversely, the mainstem traps appeared to have captured a representative sample of the Russian River age-1. smolt.

Our analysis of length frequency data for Moose River marked coho salmon smolt (Carlon and Hasbrouck 1993) captured at km 31 indicated that trap efficiency decreased with increased length (Figure 10). Coho salmon smolt in the 100 to 114 mm length range had an equal probability ($\chi^2=0.101$, $p<0.05$, 2df) of capture (approximately 1.6 to 1.7%; Table 17). Significant differences ($p=0.05$) in trap efficiency were detected at 5 to 10 mm intervals in length frequency for other smolt size ranges. The lowest calculated trap efficiency, 0.17%, was for coho smolt from 155 to 159 mm long (based on only one recovery), and none of the estimated 415 tagged fish larger than 160 mm were captured at km 31.

Seasonal trends in hydrological parameters were similar to previous years. Water level increased daily until mid-June, while temperature fluctuated between 7 and 13° C at the km 31 site throughout the study (Table 18). Total discharge was the second highest on record for May (Figure 11). Changes in water clarity were significantly correlated ($r = 0.136$, $p = 0.01$, 48 df) with changes in discharge (Figure 12).

The 1993 adult sockeye salmon return provided the first opportunity to evaluate the accuracy of smolt estimates based on adult returns of all age classes. The 1987 parent year escapement of 1,408,000 adult spawners (Table 19), produced approximately 37,000,000 age-0. fry which reared in the two major lakes in the drainage (Tarbox and King 1989). This was a minimum estimate of fry production since Russian River, Hidden Lake, and Moose River were not included. However, these systems were thought to produce only a small portion of the production that year. The 1987 parent year spawning escapement produced 30,224,000 smolt. Most of these smolt (24,416,000) migrated to sea at age-1. Some (5,807,000) 1987 brood year juveniles remained in freshwater and left as age-2. smolt the next spring. The age-1. smolt brought back 7,793,000 age-1.2 and -1.3 adults giving an age-1. smolt to adult survival of 31.9%. The return of 2,017,000 age-2.2 and -2.3 adults in 1992 and 1993 gave an age-2. smolt-to-adult survival rate of 34.7%. The total smolt to adult survival rate for the 1987 brood year was 32.5%. Survival of Tustumena Lake (Kasilof River) 1987 brood year sockeye smolt from smolt to adult was approximately 15%.

The 1988 adult spawning escapement of 910,000 produced 5,249,000 age-1. smolt and 431,000 age-2. smolt for a total smolt production of 5,680,000. Survival of age-1. smolt from the 1988 brood year was similar to 1987 with relatively few (1.9%) returning as age-1.2

adults and more (22.8%) returning as age-1.3 adults for a total survival of 1 freshwater smolt to adult of 24.7%.

The 1989 parent year adult spawning escapement of 1,379,000 produced 2,776,000 age-1. smolt and 312,000 age-2. smolt. The 1990 adult spawning escapement of 519,000 produced only 253,000 age-1. and 36,000 age-2. smolt. The 1991 spawning escapement of 431,000 fish has to date produced 797,000 smolt (age-1. only). The age-2. component of the 1991 brood year will migrate to sea in 1994.

Russian River

The Russian River inclined plane trap collected 43,791 fish from 18 May through 15 July 1993 (Table 20). Sockeye salmon fry comprised 76.1% of the catch. A total of 8,425 sockeye salmon smolt, making up 19.2% of the total, were also captured.

Dyed sockeye salmon smolt were released on 20 nights. Recapture data for these dates were grouped into seven time strata, each with a minimum of 475 released dyed sockeye salmon smolt (Table 21). Trap efficiencies by stratum ranged from 0.011 to 0.152, and were not significantly different between strata 1 and 2 ($\chi^2=0.59$, $p=0.44$, 1df), and among strata 4,5 and 6 ($\chi^2=4.36$, $p=0.11$, 2df). By combining data from statistically similar strata, we established three periods with distinct trap efficiencies. Using these data we estimated 222,024 smolt with a 95% confidence interval of 119,485 to 324,562. However, this estimate was used only for comparison of weighted length frequency distributions of various Kenai River substocks because of uncertainties in the dye and recovery process.

There were two sockeye salmon smolt migration peaks during May and June. Approximately one-fourth of the trap captures occurred between 18 May and 6 June, followed by a period of 18 days in which our maximum daily catch was 46 smolt (Table 18). The latter period accounted for less than 5% of the total catch. On 25 June, 5 days before the project was scheduled to end, catches again increased, and between that date and 15 July we counted 69.2% of the catch total for the season. The catch on the last day of operation was 1.4% of the total.

Age-2. sockeye salmon smolt were numerically dominant in the catch from mid-May until early June (Table 22). After 2 June, age-1. sockeye smolt were the most abundant age class collected. There was a significant difference (($\chi^2=1021.14$, $p<0.001$, 15df) in age class composition of the smolt captured each period except for those sampled from 1 through 15 July. Mean length and weight of age-1. smolt was at least 10 mm and 2.0 grams smaller than age-2. smolt during each of the time strata sampled.

DISCUSSION

From the beginning of the season through the time period when most of the sockeye salmon smolt migration occurred in past years, the right and left bank traps were separated by approximately 25 m. The traps closest to the middle of the river, traps 4 and 5, were approximately equidistant from their respective banks. Catches from traps placed adjacent to the shallower right bank, traps 5 and 6, contained proportionally fewer sockeye salmon smolt than those on left bank. In addition, catches of other age classes and species, especially fry, were very similar to those of the left bank near shore traps 1 and 2. Nearshore distribution of fry was also observed by Clark and Smith (1972). This catch information suggests that traps 5 and 6 were placed in areas not preferred by sockeye salmon smolt, and that large numbers of smolt were not migrating past the right bank. These data, along with the high proportion of the total sockeye salmon smolt catch in trap 3, however did not provide sufficient evidence that few smolt migrate in the section of the river between the two sets of traps.

The high relative proportion of the sockeye salmon smolt catch (48.9%) from trap 3 was not observed in previous years. Historically, traps 3 and 4 have had approximately equal seasonal catch totals. The only other year when the proportion of the catch in trap 3 exceeded that of trap 4 was 1990 when the two traps captured 46% and 33% of the total sockeye salmon smolt, respectively. Both 1990 and 1993 also had greater daily and total discharge rates for May than other study years. Since surface velocities measured at the mouth of traps 3 and 4 were essentially the same, it did not appear that the relatively high proportion of sockeye salmon smolt catches in trap 3 was solely a function of flow regime.

We decided to exclude the data from traps 5 and 6 in this year's estimate so that it would be comparable with previous years. Traps 5 and 6 accounted for 17% of all sockeye salmon smolt and 14% of the dyed smolt caught, and the ratios of dyed to undyed smolt were not different among traps 1 through 6 (χ^2=w.74, p=0.59, 5 df). When these data were included in the bootstrap model, the estimate of migrants was 548,746 smolt, an increase of 12.9% over our chosen best estimate.

Numbers of sockeye salmon smolt continued a downward trend in catch from the 161,111 in 1989, the initial year of the study. In contrast, the numbers of smolt and fry of other species have either remained relatively constant or increased. Several questions, however, remain to be answered about our estimates of trap efficiency and smolt behavior before we feel comfortable with our smolt estimates.

An important assumption underlying the population estimate is that marked and unmarked smolt behave similarly. A violation of this assumption would be apparent if we obtained very different marked to unmarked ratios among traps. Since no differences were detected among traps 1-4, we had no evidence to suggest that marked and unmarked fish behaved differently. Differences were found in previous years, so our ability to detect differences this year may have been hampered by the small number of dyed smolt recovered in 1993.

As in 1992, the minimum sample size for a single dye event was not attained. The small sample size released on any given day also precluded examination of changes in trap efficiency over time. In addition, since fewer than 10 dyed smolt were recaptured, the mark-recapture estimate could be biased (Seber 1982). Finally, the minimum number of dyed smolt needed each period was based on the assumption that trap efficiency would either equal 2%, or be consistent over time if less than 2%. Sample sizes greater than 5,700 were needed to ensure a relative error of less than 25% for efficiencies equal to or less than 1%. Since we could not meet these requirements, our estimate had very wide confidence intervals. Although neither 1992 or 1993 dyed smolt sample sizes met the sampling objectives, we elected to include both in the bootstrap procedure because the range in trap efficiencies and subsequent confidence intervals reflected the uncertainty of our estimate.

The lack of sockeye smolt captures and increase in smolt size in 1992 and 1993 have led us to seriously question the validity of our population estimator. The bootstrap technique helped alleviate some sample concerns, but since smolt were larger in 1992 and 1993 than in previous years, it is possible that the mean bootstrap estimate is conservative because larger smolt may have been able to better avoid capture. Despite these potential problems, we think that the decrease in total smolt catch relative to 1989 supports our conclusion that the 1993 seaward migration was very low.

In 1992, we were concerned that larger smolt may have a different probability of capture in our traps than smaller smolt (King et al. 1994). Prior to 1992, age-2. sockeye smolt lengths from traps samples appeared to be normally distributed (King et al. 1991) which suggested that size selectivity did not occur. We assumed that length frequency distributions would be truncated at larger values or be skewed toward smaller sizes if larger smolt were better able to evade capture. Length frequency data for Russian River, Moose River, and Hidden Creek sockeye smolt, first collected in 1992, suggested that Hidden Creek (age-1.) and Moose River (age-2.) sockeye smolt were not represented in mainstem trap catches. Their length frequency distribution had little overlap with that measured for mainstem trap smolt samples, and the corresponding mean lengths were different. In contrast, there was sufficient overlap between the mainstem and Russian River age-2. length frequency distributions to infer that Russian River smolt were at least partially represented in mainstem catches. These results were duplicated in 1993. In addition, the length frequency distribution of Russian River age-1. sockeye salmon smolt very closely resembled that of the km 31 catch age-1.

Most surprising was the low abundance of age-1. sockeye salmon smolt in the 60-70 mm size range, the size of migrants we expected to leave Skilak Lake. It is unlikely that these juveniles grew from a mean length of 59 mm measured as age-0. fry in December 1992 to a mean length of 78 mm as age-1. smolt by May 1993, since fry only grew an average 5 mm in the 2.5 months prior to the December 1992 sampling period (Tarbox and Brannian 1993). Also, sockeye salmon fry in Skilak Lake in November 1993 were 97.7% age-0. (K. Tarbox, ADF&G, Soldotna, pers comm.), eliminating holdover as a possible reason for the apparent lack of age-1. migrants from Skilak Lake. Three explanations for their absence in the trap catches can be put forward. First, smolt may have migrated out of the system during a time frame, or in an area of the river not monitored by the project. Second, the estimated 9.5

million fry inhabiting Kenai and Skilak Lakes the previous fall may have survived at a very low rate. Third, trap avoidance may have been much greater than we suspected which would have violated the assumption that probability of capture was the same for marked and unmarked smolt.

The presence of age-0. sockeye salmon smolt in the migration was unusual since we have not captured this age group in previous years. These smolt first appeared in the traps after 80-90% of the total migration had occurred. The 51 mm mean length of this age class was nearly 10 mm smaller than the average for any smolt age group we have documented in any year of the study. In addition, age-0. fry captured in the traps were uniformly 25-35 mm in length.

We examined the possibility that the age-0. sockeye salmon smolt were of Skilak Lake origin. One hypothesis was that they were actually misaged age-1. smolt. If this were true, then the age-0. smolt would not have been smaller than the 1992 age-0. Skilak Lake fall fry, unless the spring smolt were all that remained of the smallest size of the Skilak Lake 1992 fall fry, implying that only the smallest fall fry survived until spring. A second hypothesis was that these age-0. sockeye salmon were identified as smolt, but were merely 1993 recruitment that had washed out of the lake as a result of the relatively high flow rates which occurred in May. This does not appear to be the case since 1993 age-0. smolt were larger than 1993 age-0. fry sampled in July in Skilak Lake. A third hypothesis, is that the age-0. migrants came from a lake in the drainage in which age-0. fry responded to higher than average spring temperatures by smolting. No sockeye juveniles of this description were observed in the Moose River in 1993, although the weir was dismantled three days prior to the first capture at km 31. Fandrei (1993) did not report atypically small fish leaving Hidden Creek in 1993.

A comparison of length frequency distributions for coho salmon captured in Moose River, Hidden Creek and the mainstem Kenai River suggested size selectivity in trap catches (Figure 10). Carlon and Hasbrouck (1993) found a significant ($p < 0.001$) difference in mean length between coho tagged in the Moose River and those recovered in the traps, and stated that traps could not be used to estimate the number of coho salmon migrating seaward from that drainage. We found that trap efficiency could be estimated for coho salmon smolt of various size ranges, and that smolt from 100-114 mm were caught at a rate of slightly less than 2%. Since we were unable to capture Moose River and Hidden Creek sockeye salmon smolt which had similar lengths to the coho salmon smolt captured at km 31, it appears that trap efficiency differed among species as well as within a species. Similar results were reported by Thedinga et al. (1993) for screw traps used on the Situk River in Southeastern Alaska.

Mean smolt length and weight have increased dramatically since 1989. However, fry to smolt survival experienced declines of a similar or greater level during the same time period. The relationship of increased smolt size with decreased numbers has been observed in other sockeye systems (Macdonald et al. 1987). The trend in fry to smolt survival seems counter intuitive; we would expect that larger smolt to have survived at a higher rate. That the opposite has been observed suggests two possible causes: there was less competition for food in the lake after most of the overwintering fry died which allowed the survivors to grow more rapidly; or, there was a change from earlier years of the project in the relative magnitude of the tributary populations being measured at the km 31 smolt enumeration site.

The sockeye salmon smolt estimate for 1993 was considerably less than that expected from fall fry estimates adjusted for average winter survival. Fall 1992 lake surveys produced estimates of 9,506,000 age-0. and 102,300 age-1. fry in Kenai and Skilak Lakes (Tarbox and Brannian 1993). If winter survival was average (75%), approximately 7,000,000 age-1. and 77,000 age-2. smolt should have migrated from Kenai and Skilak Lakes, in addition to smolt from Hidden Lake, Moose River, and Russian River.

If our estimates were reasonably accurate, our data suggest that sockeye salmon smolt production from the 1987-1991 parent years varied considerably despite record large escapements achieved in most of those years (Table 22). The numbers of smolt per spawner declined rapidly from over 20 to less than 1, even with the production from Moose River and Hidden Lake added to the smolt estimated at km 31.

We used the estimate of Russian River sockeye salmon smolt abundance in 1993 as an index of the order of magnitude of the migration. We encountered several problems which could affect the accuracy of the estimate, and decided to alter the program in 1994 prior to generating an estimate of migration. The primary area of concern was variation in trap efficiency through time. During the period 18 May through 29 June, the trap efficiency of 0.05 was much less than expected if trap catch was proportional to area of the river sampled. Large age-2. smolt made up at least 57.0% of the migrants prior to 2 June and were absent from the samples by 30 June. During the last three weeks of the project, the migration was nearly all age-1. smolt with a mean length 11 to 17 mm less than the age-2. smolt which migrated in May and June. The age-1. smolt were recaptured at a rate of 0.13. Only if the dyed age-2. smolt were able to avoid recapture completely during the last three weeks, could we have approached the trap efficiency recorded for the early period. During the middle period, 30 June through 3 July, only 8 of 760 dyed fish were recovered. Using that trap efficiency (0.01), and the numbers of smolt captured, resulted in half the total estimated migration occurring during that period. Clearly there were enough uncertainties in the recapture results to question migration estimates. In 1994 we intend to increase the number of traps to two and weir most of the river except for a small migratory channel for adults. We hope that this will increase trap efficiency, and provide us with a clearer understanding of trap avoidance.

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Table 1. Numbers of fish captured by trap 1 in the Kenai River, May 17 through July 5, 1993.

	Numbers of Fish [a]								
Date	Sockeye Smolt	Sockeye Fry	Chinook Smolt	Chinook Fry	Coho Smolt	Coho Fry	Pink Fry	Other	Total
17–May	0	9	0	24	0	2	21	1	57
18–May	0	4	0	11	0	0	44	0	59
19–May	0	10	8	24	1	9	9	4	65
20–May	0	20	2	31	0	0	30	2	85
21–May	0	0	10	0	0	0	72	8	90
22–May	0	11	3	22	1	6	79	2	124
23–May	0	10	8	37	0	3	194	9	261
24–May	0	0	17	37	4	2	146	6	212
25–May	0	21	6	17	2	31	56	2	135
26–May	2	1	16	10	3	4	151	6	193
27–May	5	21	18	20	0	2	46	5	117
28–May	1	8	5	12	1	1	123	5	156
29–May	0	25	2	12	0	4	544	0	587
30–May	0	7	1	5	1	2	158	5	179
31–May	1	5	6	6	2	1	140	4	165
01–Jun	4	55	2	16	1	2	135	6	221
02–Jun	3	128	17	13	1	2	119	8	291
03–Jun	4	328	4	15	1	12	128	7	499
04–Jun	5	274	1	1	0	1	152	3	437
05–Jun	2	215	0	4	0	0	135	5	361
06–Jun	1	99	0	2	0	2	128	5	237
07–Jun	11	48	2	2	3	1	213	4	284
08–Jun	2	70	1	3	7	4	155	5	247
09–Jun	2	1	1	1	1	0	125	3	134
10–Jun	1	43	3	1	0	0	41	1	90
11–Jun	0	18	3	0	0	1	85	4	111
12–Jun	1	10	0	0	2	5	80	3	101
13–Jun	1	7	1	1	5	3	50	1	69
14–Jun	0	8	0	13	0	1	120	2	144
15–Jun	0	33	3	3	0	0	50	0	89
16–Jun	0	20	4	4	0	0	25	2	55
17–Jun	0	3	8	4	1	8	60	2	86
18–Jun	0	1	5	6	0	4	40	0	56
19–Jun	0	8	1	28	1	11	50	2	101
20–Jun	0	33	2	35	1	4	140	4	219
21–Jun	1	24	2	13	1	3	80	1	125
22–Jun	0	0	2	32	0	0	90	2	126
23–Jun	0	44	5	15	0	8	30	0	102
24–Jun	2	45	0	26	1	12	20	3	109
25–Jun	1	40	10	21	1	14	20	0	107
26–Jun	1	0	6	32	1	1	20	1	62
27–Jun	1	30	18	15	0	3	30	1	98
28–Jun	1	35	3	6	0	4	20	2	71
29–Jun	2	18	7	32	1	5	3	0	68
30–Jun	5	25	5	6	3	27	5	0	76
01–Jul	3	71	15	43	0	3	10	1	146
02–Jul	4	70	20	70	1	25	1	4	195
03–Jul	7	27	43	34	0	26	6	4	147
04–Jul									
05–Jul	0	56	44	32	0	19	0	6	157
Total	74	2,039	340	797	48	278	4,179	151	7,906

[a] No traps were fished on July 4.

Table 2. Numbers of fish captured by trap 2 in the Kenai River, May 17 through July 5, 1993.

	Numbers of Fish [a]								
Date	Sockeye Smolt	Sockeye Fry	Chinook Smolt	Chinook Fry	Coho Smolt	Coho Fry	Pink Fry	Other	Total
17-May	1	2	3	4	0	0	162	1	173
18-May	2	0	2	0	0	1	479	2	486
19-May	0	7	1	17	2	4	576	11	618
20-May	1	0	6	2	1	0	258	9	277
21-May	3	0	5	3	1	1	493	7	513
22-May	0	1	3	0	13	4	396	7	424
23-May	0	0	3	1	2	2	529	2	539
24-May	5	0	9	6	4	1	406	1	432
25-May	2	0	10	2	7	7	94	7	129
26-May	2	1	23	10	7	2	329	6	380
27-May	3	4	21	0	1	3	205	8	245
28-May	4	15	6	6	3	0	675	4	713
29-May	1	3	5	11	6	3	610	27	666
30-May	1	8	2	6	5	3	639	6	670
31-May	2	0	2	4	3	0	770	6	787
01-Jun	17	3	6	5	0	0	255	13	299
02-Jun	24	183	20	12	11	4	755	11	1,020
03-Jun	23	370	5	4	10	13	1032	10	1,467
04-Jun	38	196	2	0	2	0	750	7	995
05-Jun	11	175	4	3	9	2	1330	4	1,538
06-Jun	12	89	3	1	8	3	601	8	725
07-Jun	33	52	8	0	6	0	734	1	834
08-Jun	33	27	4	0	28	1	600	1	694
09-Jun	6	0	1	2	7	0	300	4	320
10-Jun	2	5	1	0	2	0	355	0	365
11-Jun	2	20	2	0	3	3	355	1	386
12-Jun	3	10	1	0	15	0	240	3	272
13-Jun	1	1	3	1	20	2	34	8	70
14-Jun	0	0	4	7	5	2	390	2	410
15-Jun	1	7	9	4	5	2	240	4	272
16-Jun	1	5	9	4	2	0	160	2	183
17-Jun	1	2	24	5	15	17	110	2	176
18-Jun	1	0	14	6	6	4	200	2	233
19-Jun	1	0	8	15	6	11	300	2	343
20-Jun	0	17	4	14	4	10	510	2	561
21-Jun	6	28	4	21	1	5	290	0	355
22-Jun	4	0	17	8	0	6	150	1	186
23-Jun	5	41	29	23	2	14	150	6	270
24-Jun	4	26	15	18	4	21	140	3	231
25-Jun	4	21	42	44	3	42	7	3	166
26-Jun	5	0	26	32	1	5	60	1	130
27-Jun	12	3	45	19	0	5	200	3	287
28-Jun	6	7	14	15	2	13	90	3	150
29-Jun	6	15	46	35	2	3	5	6	118
30-Jun	14	21	88	51	7	19	25	3	228
01-Jul	7	41	55	67	2	2	10	2	186
02-Jul	4	62	108	30	3	35	32	3	277
03-Jul	12	42	97	36	2	37	30	3	259
04-Jul									0
05-Jul	3	48	84	44	4	16	1	2	202
Total	329	1,558	903	598	252	328	17,062	230	21,260

[a] No traps were fished on July 4.

Table 3. Numbers of fish captured by trap 3 in the Kenai River, May 17 through July 5, 1993.

	Numbers of Fish [a]								
Date	Sockeye Smolt	Sockeye Fry	Chinook Smolt	Chinook Fry	Coho Smolt	Coho Fry	Pink Fry	Other	Total
17-May	0	1	0	1	0	0	376	5	383
18-May	1	0	2	0	0	0	501	6	510
19-May	2	1	2	6	1	0	364	7	383
20-May	2	1	0	0	2	2	1024	5	1,036
21-May	0	0	0	0	11	0	646	3	660
22-May	0	1	2	2	15	0	1089	2	1,111
23-May	3	2	2	1	9	3	1543	3	1,566
24-May	9	0	19	1	13	0	641	4	687
25-May	5	0	8	1	5	8	473	3	503
26-May	26	3	35	4	10	4	1425	5	1,512
27-May	47	20	20	19	7	0	1920	10	2,043
28-May	39	4	12	2	18	0	2140	9	2,224
29-May	5	6	3	8	11	0	1793	15	1,841
30-May	11	13	1	19	22	0	2720	5	2,791
31-May	39	7	4	6	16	0	1520	10	1,602
01-Jun	253	2	7	2	15	0	757	7	1,043
02-Jun	168	75	19	17	45	5	1680	11	2,020
03-Jun	77	321	16	11	41	5	2565	6	3,042
04-Jun	332	165	7	1	17	0	1280	4	1,806
05-Jun	59	130	3	4	13	2	2110	2	2,323
06-Jun	89	52	7	4	26	1	1685	5	1,869
07-Jun	251	7	11	4	36	4	2090	6	2,409
08-Jun	121	16	3	2	98	1	2385	7	2,633
09-Jun	52	0	1	0	20	0	915	2	990
10-Jun	12	2	0	0	8	0	1145	3	1,170
11-Jun	8	2	3	0	13	0	680	2	708
12-Jun	9	10	6	0	13	0	550	4	592
13-Jun	0	1	0	0	5	0	60	0	66
14-Jun	3	0	8	2	11	3	1245	3	1,275
15-Jun	2	4	7	3	7	1	450	0	474
16-Jun	3	0	25	1	15	0	360	3	407
17-Jun	5	0	29	5	64	8	250	2	363
18-Jun	7	0	25	10	27	8	670	4	751
19-Jun	14	0	22	23	16	16	580	1	672
20-Jun	1	9	11	7	3	6	790	0	827
21-Jun	7	50	4	3	7	1	1220	5	1,297
22-Jun	24	1	54	5	9	8	200	3	304
23-Jun	15	41	59	19	11	23	920	6	1,094
24-Jun	34	47	72	18	10	22	570	8	781
25-Jun	45	5	94	42	8	50	280	3	527
26-Jun	95	5	50	55	3	13	230	2	453
27-Jun	24	4	60	12	2	34	550	1	687
28-Jun	30	14	40	16	2	16	310	1	429
29-Jun	40	14	84	22	9	29	13	3	214
30-Jun	31	4	112	36	5	38	20	1	247
01-Jul	34	62	126	56	3	9	2	3	295
02-Jul	17	43	116	48	7	19	6	1	257
03-Jul	92	44	171	13	7	23	72	2	424
04-Jul									0
05-Jul	3	26	98	21	7	12	0	0	167
Total	2,146	1,215	1,460	532	723	374	44,815	203	51,468

[a] No traps were fished on July 4.

Table 4. Numbers of fish captured by trap 4 in the Kenai River, May 17 through July 3, 1993.

	Numbers of Fish [a]								
Date	Sockeye Smolt	Sockeye Fry	Chinook Smolt	Chinook Fry	Coho Smolt	Coho Fry	Pink Fry	Other	Total
17–May	0	1	0	1	0	0	296	5	298
18–May	1	0	3	0	4	0	370	5	378
19–May	0	0	0	0	2	0	237	4	239
20–May	0	2	2	2	5	0	550	7	561
21–May	0	0	1	1	4	1	560	15	567
22–May	0	1	0	3	28	0	817	4	849
23–May	3	0	2	0	7	0	781	6	793
24–May	0	0	8	0	15	1	339	10	363
25–May	4	0	3	0	9	0	88	3	104
26–May	8	0	26	2	9	0	276	8	321
27–May	19	6	22	7	10	0	290	8	354
28–May	4	1	3	2	10	0	440	9	460
29–May	4	1	3	7	30	0	510	10	555
30–May	6	0	2	8	13	0	710	13	739
31–May	20	0	3	4	15	0	750	7	792
01–Jun	96	9	12	0	8	0	312	10	437
02–Jun	60	21	13	6	32	27	971	11	1,130
03–Jun	34	141	8	0	25	5	755	5	968
04–Jun	98	108	6	2	7	0	838	3	1,059
05–Jun	15	50	2	7	20	2	1,110	3	1,206
06–Jun	24	10	4	3	23	1	830	11	895
07–Jun	81	62	2	0	38	0	1,065	5	1,248
08–Jun	22	13	2	1	52	16	1,360	4	1,466
09–Jun	6	0	3	0	16	2	576	3	603
10–Jun	6	10	0	1	3	0	808	1	828
11–Jun	4	0	2	0	17	3	460	4	486
12–Jun	2	10	1	0	23	2	400	1	438
13–Jun	0	0	3	1	46	1	185	5	236
14–Jun	1	0	4	0	16	3	630	3	654
15–Jun	1	0	13	2	17	0	220	1	253
16–Jun	0	0	21	3	16	1	180	2	221
17–Jun	2	0	33	6	59	9	120	1	229
18–Jun	3	1	28	11	30	6	230	4	309
19–Jun	2	0	17	0	11	8	440	0	478
20–Jun	2	2	9	5	5	4	700	4	727
21–Jun	6	10	11	8	4	1	420	1	460
22–Jun	16	10	27	9	5	6	120	3	193
23–Jun	8	0	45	29	5	18	50	3	155
24–Jun	8	8	54	18	1	29	120	1	238
25–Jun	9	22	80	26	5	52	220	3	414
26–Jun	24	10	26	43	1	1	30	1	135
27–Jun	8	0	46	16	0	18	350	1	438
28–Jun	7	10	32	31	2	16	150	4	248
29–Jun	8	2	86	12	3	7	6	4	124
30–Jun	4	7	75	14	10	28	20	4	158
01–Jul	5	22	88	53	3	10	10	1	191
02–Jul	6	15	63	36	3	33	5	1	161
03–Jul	14	20	113	16	2	19	29	1	213
Total	651	585	1,007	396	669	330	20,734	223	24,372

[a] No traps were fished on July 4.

Table 5. Numbers of fish captured by smolt traps 1–4 at the Kenai River km 31 site, May 17 through July 5, 1993.

	Numbers of Fish [a]								
Date	Sockeye Smolt	Sockeye Fry	Chinook Smolt	Chinook Fry	Coho Smolt	Coho Fry	Pink Fry	Other	Total
17–May	1	13	3	30	0	2	855	12	916
18–May	4	4	7	11	4	1	1394	13	1,438
19–May	2	18	11	47	6	13	1186	26	1,309
20–May	3	23	10	35	8	2	1862	23	1,966
21–May	3	0	16	4	16	2	1771	33	1,845
22–May	0	14	8	27	57	10	2381	15	2,512
23–May	6	12	15	39	18	8	3047	20	3,165
24–May	14	0	53	44	36	4	1532	21	1,704
25–May	11	21	27	20	23	46	711	15	874
26–May	38	5	100	26	29	10	2181	25	2,414
27–May	74	51	81	46	18	5	2461	31	2,767
28–May	48	28	26	22	32	1	3378	27	3,562
29–May	10	35	13	38	47	7	3457	52	3,659
30–May	18	28	6	38	41	5	4227	29	4,392
31–May	62	12	15	20	36	1	3180	27	3,353
01–Jun	370	69	27	23	24	2	1459	36	2,010
02–Jun	255	407	69	48	89	38	3525	41	4,472
03–Jun	138	1160	33	30	77	35	4480	28	5,981
04–Jun	473	743	16	4	26	1	3020	17	4,300
05–Jun	87	570	9	18	42	6	4685	14	5,431
06–Jun	126	250	14	10	57	7	3244	29	3,737
07–Jun	376	169	23	6	83	5	4102	16	4,780
08–Jun	178	126	10	6	185	22	4500	17	5,044
09–Jun	66	1	6	3	44	2	1916	12	2,050
10–Jun	21	60	4	2	13	0	2349	5	2,454
11–Jun	14	40	10	0	33	7	1580	11	1,695
12–Jun	15	40	8	0	53	7	1270	11	1,404
13–Jun	2	9	7	3	76	6	329	14	446
14–Jun	4	8	16	22	32	9	2385	10	2,486
15–Jun	4	44	32	12	29	3	960	5	1,089
16–Jun	4	25	59	12	33	1	725	9	868
17–Jun	8	5	94	20	139	42	540	7	855
18–Jun	11	2	72	33	63	22	1140	10	1,353
19–Jun	17	8	48	66	34	46	1370	5	1,594
20–Jun	3	61	26	61	13	24	2140	10	2,338
21–Jun	20	112	21	45	13	10	2010	7	2,238
22–Jun	44	11	100	54	14	20	560	9	812
23–Jun	28	126	138	86	18	63	1150	15	1,624
24–Jun	48	126	141	80	16	84	850	15	1,360
25–Jun	59	88	226	133	17	158	527	9	1,217
26–Jun	125	15	108	162	6	20	340	5	781
27–Jun	45	37	169	62	2	60	1130	6	1,511
28–Jun	44	66	89	68	6	49	570	10	902
29–Jun	56	49	223	101	15	44	27	13	528
30–Jun	54	57	280	107	25	112	70	8	713
01–Jul	49	196	284	219	8	24	32	7	819
02–Jul	31	190	307	184	14	112	44	9	891
03–Jul	125	133	424	99	11	105	137	10	1,044
04–Jul									0
05–Jul	6	130	226	97	11	47	1	8	526
Total	3,200	5,397	3,710	2,323	1,692	1,310	86,790	807	105,229

[a] No traps were fished on July 4; on July 5 only traps 1–3 were fished.

Table 6. Numbers of juvenile fish caught with inclined plane traps 1–4 in the Kenai River, 1990–1993.

Trap No.	Numbers of Fish								
	Sockeye Smolt	Sockeye Fry	Chinook Smolt	Chinook Fry	Coho Smolt	Coho Fry	Pink Fry	Other	Total
1990									
1	8,708	481	861	300	[a]	87	23	148	10,608
2	18,132	180	1,168	239	[a]	69	17	134	19,939
3	59,528	631	2,776	232	[a]	106	100	184	63,557
4	43,499	43	3,114	68	[a]	58	44	272	47,098
Total	129,867	1,335	7,919	839		320	184	738	141,202
1991									
1	1,758	62	451	131	93	27	[a]	177	2,699
2	3,291	30	918	97	224	31	[a]	161	4,752
3	10,540	23	1,526	62	775	10	[a]	200	13,136
4	10,239	17	1,697	57	832	9	[a]	182	13,033
Total	25,828	132	4,592	347	1,924	77		720	33,620
1992									
1	47	1,594	500	944	141	117	23	183	3,549
2	189	306	598	274	338	44	23	159	1,931
3	1,205	223	1,198	229	1,021	46	32	179	4,133
4	1,725	82	1,544	136	1,968	45	17	269	5,786
Total	3,166	2,205	3,840	1,583	3,468	252	95	790	15,399
1993									
1	74	2,039	340	797	48	278	4,179	151	7,906
2	329	1,558	903	598	252	328	17,062	230	21,260
3	2,146	1,215	1,460	532	723	374	44,815	203	51,468
4	651	585	1,007	396	669	330	20,734	223	24,595
Total	3,200	5,397	3,710	2,323	1,692	1,310	86,790	807	105,229

[a] No counts conducted

Table 7. Numbers of sockeye salmon smolt captured daily in the Kenai River, 1989–1993.

Date	Year					Date	Year				
	1989 [a]	1990	1991	1992	1993		1989 [a]	1990	1991	1992	1993
15–May		8				16–Jun	2,197	165	279	100	4
16–May	348	5	4	0		17–Jun	1,369	123	182	99	8
17–May	155	34	4	0	1	18–Jun	607	17	24	49	11
18–May	204	376	1	1	4	19–Jun	972	36	658	57	17
19–May	195	507	1	0	2	20–Jun	952	186	2,252	94	3
20–May	454	3,159	8	0	3	21–Jun	1,036	168	1,971	16	20
21–May	271	4,760	13	0	3	22–Jun	639	108	2,446	3	44
22–May	716	2,690	36	0	0	23–Jun	2,835	37	923	14	28
23–May	1,546	414	680	0	6	24–Jun	1,833	20	407	5	48
24–May	1,184	282	389	0	14	25–Jun	660	56	377	2	59
25–May	988	1,645	319	2	11	26–Jun	679		2,972	2	125
26–May	785	16,411	622	1	38	27–Jun	486		263	6	45
27–May	2,699	8,057	306	0	74	28–Jun			320	40	44
28–May	2,056	1,903	151	1	48	29–Jun			213	18	56
29–May	1,532	1,745	414	1	10	30–Jun			122	31	54
30–May	2,268	9,578	502	2	18	01–Jul			517		49
31–May	6,257	9,878	494	5	62	02–Jul			19		31
01–Jun	8,221	3,305	284	1	370	03–Jul			239		125
02–Jun	2,697	2,587	904	9	255	04–Jul			494		
03–Jun	4,350	8,037	459	9	138	05–Jul			10		6
04–Jun	10,170	10,182	414	56	473	06–Jul			32		
05–Jun	17,579	14,143	440	35	87	07–Jul			30		
06–Jun	49,451	8,931	262	144	126	08–Jul			40		
07–Jun	16,276	8,337	579	69	376	09–Jul			33		
08–Jun	3,482	4,430	633	28	178	10–Jul			6		
09–Jun	3,271	6,336	492	94	66						
10–Jun	2,188	429	699	69	21	TOTAL	161,111	129,868	28,173	3,166	3,200
11–Jun	988	261	525	250	14						
12–Jun	1,656	248	825	329	15						
13–Jun	1,044	93	1,296	300	2						
14–Jun	3,052	51	934	101	4						
15–Jun	763	131	654	1,123	4						

[a] Three traps were fished in 1989; four traps were fished in the remaining years.

Table 8. Comparison of catches in Kenai River traps 1–6, 1993.

Trap No.	Sockeye Smolt	Sockeye Fry	Chinook Smolt	Chinook Fry	Coho Smolt	Coho Fry	Pink Fry	Other	Total
				Numbers of Fish					
1	74	2039	340	797	48	278	4179	151	7755
2	329	1558	903	598	252	328	17062	230	21030
3	2146	1215	1460	532	723	374	44815	203	51265
4	651	585	1007	396	669	330	20734	223	24372
Total 1–4	3200	5397	3710	2323	1692	1310	86790	807	104422
5	322	2612	681	863	188	780	1739	169	7185
6	348	2650	397	1304	102	767	1267	168	6835
Total 5–6	670	5262	1078	2167	290	1547	3006	337	14020
Total	3,870	10,659	4,788	4,490	1,982	2,857	89,796	1,144	118,442
				Percent of Individual Trap Catch					
1	1.0	26.3	4.4	10.3	0.6	3.6	53.9	1.9	100.0
2	1.6	7.4	4.3	2.8	1.2	1.6	81.1	1.1	100.0
3	4.2	2.4	2.8	1.0	1.4	0.7	87.4	0.4	100.0
4	2.7	2.4	4.1	1.6	2.7	1.4	85.1	0.9	100.0
Total 1–4	3.1	5.2	3.6	2.2	1.6	1.3	83.1	0.8	100.0
5	4.5	36.4	9.5	12.0	2.6	10.9	24.2	2.4	100.0
6	5.1	38.8	5.8	19.1	1.5	11.2	18.5	2.5	100.0
Total 5–6	4.8	37.5	7.7	15.5	2.1	11.0	21.4	2.4	100.0
Total	3.3	9.0	4.0	3.8	1.7	2.4	75.8	1.0	100.0
				Percent of Total Catch					
1	0.1	1.7	0.3	0.7	0.0	0.2	3.5	0.1	6.5
2	0.3	1.3	0.8	0.5	0.2	0.3	14.4	0.2	17.8
3	1.8	1.0	1.2	0.4	0.6	0.3	37.8	0.2	43.3
4	0.5	0.5	0.9	0.3	0.6	0.3	17.5	0.2	20.6
Total 1–4	2.7	4.6	3.1	2.0	1.4	1.1	73.3	0.7	88.2
5	0.3	2.2	0.6	0.7	0.2	0.7	1.5	0.1	6.1
6	0.3	2.2	0.3	1.1	0.1	0.6	1.1	0.1	5.8
Total 5–6	0.6	4.4	0.9	1.8	0.2	1.3	2.5	0.3	11.8
Total	3.3	9.0	4.0	3.8	1.7	2.4	75.8	1.0	100.0

Table 9. Numbers of fish captured by trap 5 in the Kenai River, May 17 through July 2, 1993.

Date	Sockeye Smolt	Sockeye Fry	Chinook Smolt	Chinook Fry	Coho Smolt	Coho Fry	Pink Fry	Other	Total
	Numbers of Fish								
17–May	0	0	0	0	0	0	11	0	11
18–May	1	2	2	46	1	0	66	4	122
19–May	1	8	1	24	0	3	43	0	80
20–May	0	2	0	19	1	1	68	0	91
21–May	2	2	1	39	7	0	32	2	85
22–May	0	6	0	32	1	6	28	2	75
23–May	1	10	8	20	0	3	80	0	122
24–May	5	1	7	32	4	9	120	1	179
25–May	6	29	2	15	3	15	43	2	115
26–May	18	2	28	46	2	3	41	9	149
27–May	32	35	25	6	2	1	10	12	123
28–May	10	8	6	13	3	3	59	7	109
29–May	5	47	2	14	3	23	28	3	125
30–May	2	54	3	19	7	3	39	3	130
31–May	5	2	4	11	4	8	47	9	90
01–Jun	16	58	14	71	9	6	131	3	308
02–Jun	15	73	8	75	6	27	173	9	386
03–Jun	24	585	4	28	11	19	58	10	739
04–Jun	48	362	0	1	5	3	172	8	599
05–Jun	14	590	3	8	1	2	55	5	678
06–Jun	5	115	3	13	9	8	48	11	212
07–Jun	5	6	0	1	0	1	36	0	49
08–Jun	20	134	2	10	11	2	131	15	325
09–Jun	11	37	1	3	5	3	38	3	101
10–Jun	9	46	1	1	6	0	15	2	80
11–Jun	0	21	6	0	4	5	3	3	42
12–Jun	0	10	3	1	4	12	20	3	53
13–Jun	1	18	3	0	6	17	16	4	65
14–Jun	0	10	1	8	0	10	3	1	33
15–Jun	1	9	24	9	2	2	4	0	51
16–Jun	1	9	46	14	8	1	2	1	82
17–Jun	0	1	45	11	25	34	0	1	117
18–Jun	3	8	29	10	5	24	30	2	111
19–Jun	2	27	22	6	3	15	3	3	81
20–Jun	2	19	4	23	4	21	50	1	124
21–Jun	14	20	16	24	5	17	2	2	100
22–Jun	1	51	8	3	6	46	2	5	122
23–Jun	4	26	24	13	3	32	0	2	104
24–Jun	7	31	35	13	4	90	5	2	187
25–Jun	5	11	67	31	0	35	0	1	150
26–Jun	5	3	23	35	0	20	2	2	90
27–Jun	6	15	22	10	1	28	10	2	94
28–Jun	1	9	12	14	1	44	0	3	84
29–Jun	2	12	26	15	0	33	5	1	94
30–Jun	3	10	31	12	3	35	0	2	96
01–Jul	7	22	93	27	2	46	10	2	209
02–Jul	2	56	16	37	1	64	0	6	182
Total	322	2,612	681	863	188	780	1,739	169	7,354

Table 10. Numbers of fish captured by trap 6 in the Kenai River, May 17 through July 2, 1993.

Date	Numbers of Fish								
	Sockeye Smolt	Sockeye Fry	Chinook Smolt	Chinook Fry	Coho Smolt	Coho Fry	Pink Fry	Other	Total
17–May	0	0	0	0	0	0	4	0	4
18–May	0	0	0	23	0	0	26	0	49
19–May	0	3	0	13	4	2	15	3	37
20–May	0	6	1	12	0	0	22	0	41
21–May	0	1	0	31	1	0	16	2	49
22–May	0	22	0	42	0	5	13	4	82
23–May	1	10	1	27	0	0	18	2	57
24–May	3	0	1	24	1	1	30	2	60
25–May	2	19	0	15	0	9	3	1	48
26–May	12	3	2	53	0	0	45	4	115
27–May	39	39	3	12	1	7	11	4	112
28–May	7	13	8	34	2	0	58	12	122
29–May	3	49	3	21	1	7	34	5	118
30–May	2	27	0	9	4	5	1	2	48
31–May	1	0	1	15	0	4	31	3	52
01–Jun	7	39	1	53	2	2	120	4	224
02–Jun	12	92	4	42	2	5	140	17	297
03–Jun	11	596	7	442	6	25	34	9	1,121
04–Jun	53	272	1	0	1	10	148	4	485
05–Jun	8	270	2	11	1	1	50	1	343
06–Jun	5	176	2	14	0	8	48	6	253
07–Jun	50	148	5	1	5	11	45	8	265
08–Jun	22	100	9	14	3	4	105	7	257
09–Jun	7	60	2	0	2	1	50	3	122
10–Jun	5	103	0	3	2	0	13	0	126
11–Jun	1	25	2	0	8	2	11	3	49
12–Jun	3	13	1	1	7	7	23	1	55
13–Jun	0	17	2	0	3	9	12	4	43
14–Jun	0	30	0	3	5	17	1	2	56
15–Jun	1	8	14	3	4	1	0	4	31
16–Jun	3	16	38	8	0	4	0	2	69
17–Jun	3	23	33	10	12	27	30	1	138
18–Jun	2	6	18	14	4	14	30	4	88
19–Jun	3	39	13	4	5	8	5	4	77
20–Jun	2	31	1	32	2	11	30	4	109
21–Jun	19	13	0	29	1	14	11	2	87
22–Jun	2	55	9	7	1	38	3	4	115
23–Jun	11	46	11	24	2	59	5	6	158
24–Jun	4	25	39	22	4	98	0	4	192
25–Jun	7	16	54	34	1	53	10	3	175
26–Jun	7	14	12	50	0	2	0	0	85
27–Jun	10	49	22	30	0	10	0	3	121
28–Jun	4	14	10	19	0	25	5	1	77
29–Jun	4	25	7	25	1	49	0	2	111
30–Jun	6	31	14	14	0	80	1	2	146
01–Jul	3	42	31	34	3	62	10	5	185
02–Jul	3	64	13	30	1	70	0	4	181
Total	348	2,650	397	1,304	102	767	1,267	168	6,835

Table 11. Dyed Kenai River sockeye salmon smolt releases and recaptures by date, 1993.

Date	Number of Fish Dyed	Numbers of Dyed Fish Released	Capture to Release Survival [a]	Number of Dyed Fish Recovered	Trap Efficiency
02–Jun	313	291	0.930	0	
03–Jun	179	162	0.905	0	
04–Jun	678	632	0.932	4	
05–Jun	112	107	0.955	0	
06–Jun	137	124	0.905	0	
07–Jun	446	402	0.901	2	
08–Jun	223	216	0.969	0	
Total		1934	0.926	6	0.003

[a] Number of dyed fish released/Number of dyed fish.

Table 12. Results of sockeye salmon smolt dye tests conducted on the Kenai River, 1989–1993.

Date	Number of Fish Dyed	Number of Dyed Fish Recovered	Trap Efficiency
1989 total	12,599	86	0.007
1990 period 1	2,793	21	0.008
1990 period 2–4	8,409	109	0.013
1991 total	1,923	19	0.010
1992 total	926	19	0.021
1993 total	1,934	6	0.003

Table 13. Estimated daily sockeye salmon smolt seaward migration from the Kenai River, 1993.

Date	Daily Sockeye Smolt Trap Catch	Estimate of Sockeye Smolt Migration [a] Daily	Cumulative	Age-0.	Age-1.	Age-2.
17-May	1	152	152	0	118	34
18-May	4	608	760	0	471	137
19-May	2	304	1,064	0	235	68
20-May	3	456	1,519	0	353	103
21-May	3	456	1,975	0	353	103
22-May	0	0	1,975	0	0	0
23-May	6	912	2,887	0	706	205
24-May	14	2,127	5,014	0	1,648	479
25-May	11	1,671	6,685	0	1,295	376
26-May	38	5,773	12,458	0	4,473	1,300
27-May	74	11,243	23,701	0	8,711	2,532
28-May	48	7,293	30,994	0	5,650	1,642
29-May	10	1,519	32,513	0	1,177	342
30-May	18	2,735	35,248	0	2,119	616
31-May	62	9,420	44,668	0	7,299	2,121
01-Jun	370	56,215	100,883	0	55,525	690
02-Jun	255	38,743	139,625	0	38,267	475
03-Jun	138	20,967	160,592	0	20,709	257
04-Jun	473	71,864	232,455	0	70,982	882
05-Jun	87	13,218	245,673	0	13,056	162
06-Jun	126	19,143	264,817	0	18,908	235
07-Jun	376	57,126	321,943	0	56,425	701
08-Jun	178	27,044	348,987	0	26,712	332
09-Jun	66	10,027	359,014	0	9,904	123
10-Jun	21	3,191	362,205	0	3,151	39
11-Jun	14	2,127	364,332	0	2,101	26
12-Jun	15	2,279	366,611	0	2,251	28
13-Jun	2	304	366,915	0	300	4
14-Jun	4	608	367,522	0	600	7
15-Jun	4	608	368,130	0	600	7
16-Jun	4	608	368,738	281	326	0
17-Jun	8	1,215	369,953	563	653	0
18-Jun	11	1,671	371,625	774	898	0
19-Jun	17	2,583	374,207	1,196	1,387	0
20-Jun	3	456	374,663	211	245	0
21-Jun	20	3,039	377,702	1,407	1,632	0
22-Jun	44	6,685	384,387	3,095	3,590	0
23-Jun	28	4,254	388,641	1,969	2,285	0
24-Jun	48	7,293	395,934	2,094	5,152	47
25-Jun	59	8,964	404,898	2,574	6,333	58
26-Jun	125	18,991	423,889	5,452	13,417	123
27-Jun	45	6,837	430,726	1,963	4,830	44
28-Jun	44	6,685	437,411	1,919	4,723	43
29-Jun	56	8,508	445,919	3,135	5,346	28
30-Jun	54	8,204	454,123	3,023	5,155	27
01-Jul	49	7,445	461,568	2,743	4,677	24
02-Jul	31	4,710	466,278	1,735	2,959	15
03-Jul	125	18,991	485,269	6,997	11,932	62
04-Jul	[b]					
05-Jul	6	912	486,181	336	573	3
Total	3,200	486,181		41,465	430,213	14,503

[a] Total migration- 486,181. Lower confidence interval- 163,998; Upper confidence interval- 1,202,844.
[b] No traps were fished on 4 July; only traps 1-3 were fished on 5 July.

Table 14. Cumulative proportion of sockeye salmon smolt seaward migration by day, 1989–1993.

Date	Age–1. 1989	1990	1991	1992	1993	Age–2. 1989	1990	1991	1992	1993
15–May		0.000					0.000			
16–May	0.002	0.000	0.000	0.000		0.002	0.000	0.001	0.000	
17–May	0.003	0.000	0.000	0.000	0.000	0.003	0.001	0.002	0.000	0.002
18–May	0.004	0.004	0.000	0.000	0.001	0.004	0.007	0.002	0.000	0.012
19–May	0.006	0.008	0.000	0.000	0.002	0.006	0.015	0.002	0.000	0.017
20–May	0.008	0.036	0.000	0.000	0.003	0.008	0.067	0.004	0.000	0.024
21–May	0.010	0.078	0.000	0.000	0.004	0.010	[a] 0.146	0.007	0.000	0.031
22–May	0.015	0.101	0.000	0.000	0.004	0.015	0.190	0.015	0.000	0.031
23–May	0.024	0.105	0.003	0.000	0.005	0.024	0.197	0.169	0.000	0.045
24–May	0.031	0.106	0.005	0.000	0.009	0.031	0.200	0.256	0.000	0.078
25–May	0.038	0.112	0.007	0.001	0.012	0.038	0.217	0.328	0.001	0.104
26–May	0.042	0.169	0.010	0.001	0.022	0.042	0.387	0.469	0.001	0.193
27–May	0.059	0.197	0.011	0.001	0.043	0.059	0.471	0.538	0.001	0.368
28–May	0.072	0.204	0.015	0.001	0.056	0.072	0.490	0.550	0.002	0.481
29–May	0.082	0.216	0.027	0.002	0.059	0.082	0.503	0.583	0.002	0.505
30–May	0.096	0.282	0.041	0.002	0.063	0.096	0.574	0.624	0.003	0.547
31–May	0.134	0.350	0.055	0.004	0.080	0.134	0.647	0.664	0.004	0.694
01–Jun	0.185	0.373	0.063	0.004	0.210	0.185	0.672	0.687	0.004	0.741
02–Jun	0.202	0.391	0.089	0.007	0.298	0.202	0.691	0.759	0.007	0.774
03–Jun	0.229	0.469	0.102	0.009	0.347	0.229	0.730	0.797	0.010	0.792
04–Jun	0.292	0.569	0.113	0.026	0.512	0.292	0.781	0.830	0.028	0.852
05–Jun	0.401	0.706	0.126	0.036	0.542	0.401	0.851	0.865	0.039	0.864
06–Jun	0.708	0.793	0.133	0.079	0.586	0.708	0.895	0.887	0.086	0.880
07–Jun	0.809	0.874	0.155	0.099	0.717	0.809	0.936	0.898	0.108	0.928
08–Jun	0.831	0.918	0.179	0.107	0.779	0.831	0.958	0.910	0.117	0.951
09–Jun	0.851	0.979	0.198	0.135	0.802	0.851	0.989	0.919	0.147	0.960
10–Jun	0.865	0.983	0.225	0.155	0.809	0.865	0.992	0.933	0.169	0.962
11–Jun	0.871	0.986	0.245	0.206	0.814	0.871	0.993	0.943	0.254	0.964
12–Jun	0.881	0.988	0.277	0.272	0.820	0.881	0.994	0.950	0.366	0.966
13–Jun	0.888	0.989	0.329	0.332	0.820	0.888	0.995	0.962	0.467	0.966
14–Jun	0.907	0.990	0.366	0.352	0.822	0.907	0.995	0.970	0.502	0.967
15–Jun	0.911	0.991	0.392	0.578	0.823	0.911	0.995	0.976	0.883	0.967
16–Jun	0.925	0.993	0.403	0.657	0.824	0.925	0.996	0.979	0.905	0.967
17–Jun	0.934	0.994	0.411	0.735	0.825	0.934	0.997	0.980	0.927	0.967
18–Jun	0.937	0.994	0.412	0.773	0.827	0.937	0.997	0.980	0.937	0.967
19–Jun	0.943	0.994	0.438	0.818	0.831	0.943	0.997	0.983	0.950	0.967
20–Jun	0.949	0.996	0.530	0.892	0.831	0.949	0.998	0.991	0.970	0.967
21–Jun	0.956	0.998	0.610	0.905	0.835	0.956	0.999	0.998	0.974	0.967
22–Jun	0.960	0.999	0.711	0.907	0.843	0.960	0.999	0.998	0.974	0.967
23–Jun	0.977	0.999	0.749	0.918	0.849	0.977	1.000	0.999	0.977	0.967
24–Jun	0.989	0.999	0.766	0.922	0.861	0.989	1.000	0.999	0.978	0.970
25–Jun	0.993	1.000	0.781	0.924	0.875	0.993	1.000	0.999	0.979	0.974
26–Jun	0.997		0.904	0.925	0.907	0.997		0.999	0.979	0.983
27–Jun	1.000		0.914	0.930	0.918	1.000		1.000	0.981	0.986
28–Jun			0.928	0.961	0.929			1.000	0.989	0.989
29–Jun			0.936	0.976	0.941			1.000	0.993	0.991
30–Jun			0.941	1.000	0.953			1.000	1.000	0.993
01–Jul			0.963		0.964			1.000		0.994
02–Jul			0.964		0.971			1.000		0.995
03–Jul			0.973		0.999			1.000		1.000
04–Jul			0.994		0.999			1.000		1.000
05–Jul			0.994		1.000			1.000		1.000
06–Jul			0.996					1.000		
07–Jul			0.997					1.000		
08–Jul			0.998					1.000		
09–Jul			1.000					1.000		
10–Jul			1.000					1.000		

[a] Shaded blocks highlight .1 proportion increments

Table 15. Summary of Kenai River sockeye salmon smolt age composition, 1989–1993. Data collected at river km 31.

Sample Period	Percent of Seaward Migration Age–0.	Age–1.	Age–2.	Age–3.	Sample Size
5/15–5/23/90	0.0	31.9	68.1	0.0	756
5/24–5/28/90	0.0	22.8	76.7	0.5	427
5/29–6/2/90	0.0	45.0	54.7	0.3	424
6/3–6/25/90	0.0	63.4	36.6	0.0	1,815
5/16–5/27/91	0.0	11.3	88.5	0.2	425
5/28–6/6/91	0.0	68.4	31.6	0.0	850
6/7–6/11/91	0.0	92.5	7.5	0.0	425
6/12–6/17/91	0.0	96.5	3.5	0.0	425
6/18–6/21/91	0.0	98.6	1.4	0.0	425
6/22–7/15/91	0.0	99.9	0.1	0.0	1,190
5/16–6/10/92	0.0	16.1	83.9	0.0	348
6/11–6/15/92	0.0	11.0	89.0	0.0	319
6/16–6/30/92	0.0	43.0	57.0	0.0	314
5/17–5/31/93	0.0	77.4	22.6	0.0	262
6/1–6/15/93	0.0	98.8	1.2	0.0	163
6/16–6/23/93	46.3	53.7	0.0	0.0	162
6/24–6/28/93	28.7	70.6	0.6	0.0	310
6/29–7/6/93	36.8	62.8	0.3	0.0	304
Season Summary					
1989	0.0	99.7	0.3	0.0	3,557
1990	0.0	46.7	53.1	0.2	3,422
1991	0.0	86.1	13.9	0.0	3,740
1992	0.0	17.3	82.7	0.0	981
1993	8.5	88.5	3.0	0.0	1,200

Table 16. Sockeye salmon smolt mean length and weight by age class and time strata, 1989-1993. Data collected at river km 31.

			Length						Weight					
Year	Time Period	Age	N	Mean	Min.	Max.	Var.	Stand. Dev.	N	Mean	Min.	Max.	Var.	Stand. Dev.
93	6/1-23	0.	75	51	44	78	25	5	75	1.4	0.9	4.2	0.2	0.5
93	6/24-28	0.	89	52	41	64	18	4	89	1.4	0.7	2.5	0.1	0.4
93	6/29-7/6	0.	112	54	43	74	27	5	112	1.7	0.9	3.9	0.2	0.5
89	5/16-20	1.	413	60	46	80	19	4	413	1.9	0.8	4.3	0.18	0.42
89	5/21-25	1.	338	61	60	72	22	5	338	2.1	1.2	3.3	0.13	0.38
89	5/26-30	1.	421	60	53	77	17	4	421	1.9	1.2	3.8	0.15	0.39
89	5/31-6/04	1.	424	59	49	70	13	4	424	1.8	1.0	3.4	0.13	0.36
89	6/06-09	1.	423	59	46	73	15	4	424	1.8	0.8	3.7	0.15	0.39
89	6/10-14	1.	425	58	49	74	14	4	425	1.8	1.1	3.5	0.12	0.35
89	6/15-6/19	1.	429	58	46	75	17	4	429	1.8	0.2	4.0	0.20	0.45
89	6/20-27	1.	679	60	19	85	19	4	679	2.1	1.0	5.4	0.26	0.51
90	5/15-23	1.	241	65	48	82	30	5	241	2.2	1.0	4.2	0.34	0.59
90	5/24-28	1.	97	63	52	78	25	5	97	2.0	1.0	3.8	0.27	0.52
90	5/29-6/02	1.	191	61	47	90	25	5	191	1.9	0.8	5.3	0.28	0.53
90	6/03-25	1.	1,150	70	52	138	53	7	1,150	3.1	1.0	23.8	2.17	1.47
91	5/23-27	1.	48	73	52	110	92	10	48	3.4	1.8	10.4	2.15	1.47
91	5/28-6/01	1.	292	65	52	89	41	6	292	2.3	1.1	5.5	0.55	0.74
91	6/02-06	1.	289	67	55	100	44	7	289	2.5	1.3	7.4	0.75	0.86
91	6/07-11	1.	393	64	50	79	16	4	393	2.4	1.2	4.8	0.22	0.46
91	6/13-17	1.	410	65	49	84	16	4	410	2.7	1.2	5.9	0.31	0.56
91	6/18-21	1.	419	65	50	79	21	5	419	2.8	1.3	5.6	0.40	0.63
91	6/22-25	1.	340	66	50	84	19	4	340	2.9	1.3	5.6	0.34	0.58
91	6/26-30	1.	424	65	50	75	11	3	424	2.7	1.2	4.3	0.21	0.46
91	7/01-05	1.	425	67	54	80	13	4	425	3.1	1.5	5.9	0.31	0.55
92	6/05-10	1.	56	74	60	90	54	7	28	3.9	2.5	6.3	1.21	1.10
92	6/11-15	1.	35	78	66	95	35	6	17	5.1	3.2	10.7	3.03	1.74
92	6/16-29	1.	135	78	58	130	86	9	97	4.7	1.9	22.0	5.33	2.31
93	5/17-31	1.	203	76	59	124	81	9	145	4.4	2.0	19.7	3.5	1.9
93	6/1-23	1.	248	77	60	93	45	7	248	4.2	1.8	7.4	1.4	1.2
93	6/24-28	1.	219	80	62	90	18	4	219	4.9	2.3	8.2	0.7	0.8
93	6/29-7/6	1.	191	79	65	90	17	4	191	5.0	2.9	6.6	0.4	0.7
90	5/15-23	2.	515	74	62	123	21	5	515	3.2	1.9	13.4	0.55	0.74
90	5/24-28	2.	326	74	61	115	35	6	326	3.2	1.8	8.8	0.68	0.82
90	5/29-6/02	2.	232	74	62	104	43	7	232	3.2	1.2	8.9	1.12	1.06
90	6/03-25	2.	665	75	60	102	28	5	665	3.7	1.8	7.8	0.71	0.84
91	5/23-27	2.	376	80	71	108	29	5	376	4.2	2.8	10.7	1.07	1.03
91	5/28-6/01	2.	133	79	70	101	32	6	133	4.1	3.0	8.9	1.01	1.01
91	6/02-06	2.	136	79	68	110	41	6	136	4.2	2.5	10.1	1.30	1.14
91	6/07-11	2.	32	78	70	91	25	5	32	4.1	2.4	6.3	0.85	0.92
91	6/13-17	2.	15	76	68	86	20	4	15	4.0	3.3	5.2	0.29	0.54
92	6/05-10	2.	292	97	71	117	62	8	151	7.7	3.3	11.2	2.73	1.65
92	6/11-15	2.	284	89	76	110	22	5	156	6.9	4.3	10.4	1.08	1.04
92	6/16-29	2.	179	89	69	111	20	4	134	6.5	3.2	12.0	1.16	1.08
93	5/17-31	2.	59	99	86	115	47	7	33	8.5	6.1	14.0	3.6	1.9

Table 17. Comparison of trap efficiency by length for Moose River coho salmon, 1993.

	Km 31 Enumeration Site Tagged Coho Smolt Recovered				Moose River Weir Coho Smolt [a]						
	Length Frequency Distribution				Length Frequency Distribution				Proportion of Total Tagged Smolt	Estimated Total Number of Tagged Smolt	Trap Efficiency [b]
	Age-1.	Age-2.	Age-3.	Total	Age-1.	Age-2.	Age-3.	Total			
90-94	0			0	1			1	0.001	82	0.0000
95-99	0	0		0	0	0		0	0.000	0	
100-104	3	5		8	3	3		6	0.005	491	0.0163
105-109	14	23		37	8	20		28	0.023	2292	0.0161
110-114	12	50	0	62	5	39		44	0.036	3602	0.0172
115-119	9	97	1	107	4	112	0	116	0.095	9496	0.0113
120-124	4	107	1	112	2	171	8	181	0.149	14818	0.0076
125-129	3	79	1	83	4	250	4	258	0.212	21121	0.0039
130-134	0	47	4	51	0	200	10	210	0.173	17192	0.0030
135-139		21	5	26	1	149	23	173	0.142	14163	0.0018
140-144		13	2	15	1	83	27	111	0.091	9087	0.0017
145-149		3	0	3	1	29	14	44	0.036	3602	0.0008
150-154		2	2	4	0	15	10	25	0.021	2047	0.0020
155-159		0	1	1		3	4	7	0.006	573	0.0017
160-164		1	2	3		4	3	7	0.006	573	0.0052
165-169		0	0	0		1	1	2	0.002	164	0.0000
170-174		0		0		0	2	2	0.002	164	0.0000
175-179		0		0			1	1	0.001	82	0.0000
Total	45	449	19	513	30	1079	108	1217			
Proportion	0.088	0.875	0.037	1	0.025	0.887	0.089	1			

[a] We assumed that the length frequency distribution of coho smolt sampled at the weir were representative of all tagged smolt.

[b] Trap efficiency of the km 31 traps for moose river tagged coho smolt. Defined as the trap catch divided by the estimated total number of smolt tagged at the weir.

Table 18. River characteristics measured daily at the Kenai River km 31 smolt enumeration site, 1993.

Date	Level Reading (cm)	Level Change (cm)	Turbidity Reading (cm)	Turbidity Change (cm)	Temp. (°c)	Velocity (fps) Trap 1	Trap 2	Trap 3	Trap 4	Trap 5	Trap 6
17–May	3		76		7						
18–May	6	3	76	0	8						
19–May	9	1	81	5	8	3.1	3.4	3.4	3.5	3.3	3.8
20–May	10	5	84	3	8						
21–May	15	9	81	−3	8						
22–May	24	2	71	−10	10						
23–May	26	4	66	−5	8	3.8	3.8	3.9	3.8	3.7	3.8
24–May	30	3	61	−5	8						
25–May	34	6	61	0	10						
26–May	40	0	56	−5	8	3.2	3.8	3.8	4.0	4.2	3.0
27–May	40	3	61	5	7						
28–May	43	0	99	38	8						
29–May	43	6	135	36	10						
30–May	49	1	102	−33	10						
31–May	49	5	107	5	11						
01–Jun	55	6	94	−13	7						
02–Jun	61	6	64	−30	9						
03–Jun	67	12	81	18	10						
04–Jun	79	12	66	−15	12	3.8	4.1	4.0	3.9	3.8	3.8
05–Jun	91	12	89	23	9						
06–Jun	104	−21	84	−5	13						
07–Jun	82	0	86	3	9						
08–Jun	82	−3	107	20	8						
09–Jun	79	−3	119	13	9						
10–Jun	76	3	132	13	9						
11–Jun	79	−3	130	−3	8						
12–Jun	76	3	137	8	8						
13–Jun	79	−3	135	−3	9						
14–Jun	76	0	140	5	9						
15–Jun	76	−3	137	−3	8						
16–Jun	73	−3	137	0	8						
17–Jun	70	3	140	3	8						
18–Jun	73	0	152	13	9						
19–Jun	73	0	157	5	11						
20–Jun	73	3	157	0	13						
21–Jun	76	−3	135	−23	12						
22–Jun	73	6	135	0	13						
23–Jun	79	3	147	13	11						
24–Jun	82	−3	91	−56	10						
25–Jun	79	0	102	10	12						
26–Jun	79	0	112	10	13						
27–Jun	79	0	112	0	13						
28–Jun	79	3	91	−20	13						
29–Jun	82	3	107	15	12						
30–Jun	85	0	122	15	12						
01–Jul	85	0	107	−15	12						
02–Jul	85	1	107	0	12						
03–Jul	86	1	91	−15	12						
04–Jul	87	2	91	0	10						
05–Jul	88	2	81	−10	10						
06–Jul	90	2	99	18	13						

Table 19. Sockeye salmon adult escapement and smolt production in the Kenai River, 1986–1993.

Brood Year	Total Spawning Escapement	Number of Smolt Produced Age-1.	Age-2.	Age-3.	Total	Smolt per Spawner
1986	422,000	[a]	115,000 [b]	16,000		
1987	1,408,000	24,416,000 [b]	5,807,000 [b]	1,000	30,224,000	21.5
1988	910,000	5,249,000 [b]	431,000 [b]	0	5,680,000	6.2
1989	1,379,000	2,776,000 [b]	312,000 [c]	0	3,088,000	2.2
1990	519,000	253,000 [c]	36,000 [c]	[d]	289,000	0.6
1991	431,000	797,000 [c]	[d]			
1992	807,000					
1993	697,000					

[a] No data collected.

[b] Includes Hidden Lake migration not thought to be captured by the km 31 inclined plane traps.

[c] Includes Hidden Lake (Fandrei 1993) and Moose River migration not thought to be captured by the km 31 inclined plane traps.

[d] Migrate as smolt in 1994.

Table 20. Numbers of fish captured by smolt trap from the Russian River, May 18 through July 15, 1993.

	Daily Sockeye Smolt Trap Catch			Numbers of Fish							
Date	Number	Daily Proportion	Cumulative Proportion	Sockeye Fry[a]	Chinook Smolt	Chinook Fry	Coho Smolt	Coho Fry	Pink Fry	Other	Total
18–May	16	0.002	0.002	2,000	0	0	2	0	0	1	2,019
19–May	15	0.002	0.004	3,500	0	0	10	0	0	10	3,535
20–May	59	0.007	0.011	5,000	1	1	1	0	0	10	5,072
21–May	60	0.007	0.018	3,500	0	1	1	0	0	8	3,570
22–May	138	0.016	0.034	2,500	0	1	0	0	0	9	2,648
23–May	37	0.004	0.039	2,000	0	0	0	0	0	5	2,042
24–May	47	0.006	0.044	1,000	1	0	0	3	0	4	1,055
25–May	60	0.007	0.051	1,500	0	6	0	4	0	10	1,580
26–May	355	0.042	0.093	650	0	0	0	7	0	11	1,023
27–May	165	0.020	0.113	750	6	0	2	2	0	22	947
28–May	124	0.015	0.128	450	3	0	0	8	0	5	590
29–May	209	0.025	0.153	1,400	0	2	0	4	0	14	1,629
30–May	179	0.021	0.174	2,100	6	1	1	0	0	12	2,299
31–May	148	0.018	0.191	2,000	6	0	0	3	0	7	2,164
01–Jun	25	0.003	0.194	2,400	0	20	1	0	0	23	2,469
02–Jun	213	0.025	0.220	1,400	2	0	0	7	0	15	1,637
03–Jun	60	0.007	0.227	500	4	1	0	4	0	17	586
04–Jun	46	0.005	0.232	275	7	0	20	3	0	3	354
05–Jun	48	0.006	0.238	150	4	0	23	1	0	7	233
06–Jun	192	0.023	0.261	100	3	0	24	2	0	23	344
07–Jun	46	0.005	0.266	20	10	1	27	6	0	15	125
08–Jun	9	0.001	0.267	0	1	0	30	0	0	3	43
09–Jun	28	0.003	0.271	15	7	0	47	5	0	3	105
10–Jun	8	0.001	0.271	0	4	0	50	1	0	7	70
11–Jun	19	0.002	0.274	10	7	3	17	1	0	10	67
12–Jun	8	0.001	0.275	45	0	0	17	0	0	20	90
13–Jun	26	0.003	0.278	2	3	0	23	2	0	3	59
14–Jun	32	0.004	0.282	4	0	0	2	2	0	0	40
15–Jun	6	0.001	0.282	0	0	0	0	0	0	4	10
16–Jun	3	0.000	0.283	0	0	0	0	0	0	2	5
17–Jun	25	0.003	0.286	0	1	5	5	1	0	3	40
18–Jun	29	0.003	0.289	3	0	0	6	0	0	1	39
19–Jun	12	0.001	0.290	0	0	0	1	2	0	2	17
20–Jun	35	0.004	0.295	0	2	0	2	3	0	3	45
21–Jun	30	0.004	0.298	0	1	1	0	0	0	0	32
22–Jun	9	0.001	0.299	0	0	0	0	0	0	5	14
23–Jun	33	0.004	0.303	0	0	0	2	0	0	1	36
24–Jun	39	0.005	0.308	0	1	1	0	0	0	3	44
25–Jun	170	0.020	0.328	0	2	2	6	0	0	8	188
26–Jun	323	0.038	0.366	3	0	0	3	0	0	4	333
27–Jun	202	0.024	0.390	5	1	0	3	0	0	8	219
28–Jun	202	0.024	0.414	0	0	2	8	5	0	6	223
29–Jun	220	0.026	0.440	0	4	2	2	0	0	24	252
30–Jun	239	0.028	0.469	0	3	1	3	8	0	16	270
01–Jul	260	0.031	0.500	0	5	11	3	0	0	20	299
02–Jul	398	0.047	0.547	4	1	2	4	10	0	15	434
03–Jul	227	0.027	0.574	0	1	5	5	17	0	9	264
04–Jul	361	0.043	0.617	0	1	8	19	1	0	17	407
05–Jul	371	0.044	0.661	0	7	5	29	9	0	10	431
06–Jul	252	0.030	0.691	1	1	6	20	19	0	10	309
07–Jul	302	0.036	0.726	0	0	31	27	6	0	18	384
08–Jul	509	0.060	0.787	0	1	6	25	19	0	19	579
09–Jul	414	0.049	0.836	11	5	0	46	26	0	11	513
10–Jul	390	0.046	0.882	16	2	10	33	7	0	7	465
11–Jul	263	0.031	0.913	0	2	3	16	9	0	8	301
12–Jul	299	0.035	0.949	0	3	0	47	12	0	7	368
13–Jul	162	0.019	0.968	0	1	0	50	0	0	5	218
14–Jul	148	0.018	0.986	0	1	0	44	0	0	7	200
15–Jul	120	0.014	1.000	0	0	0	29	300	0	8	457
TOTAL	8,425			33,314	121	138	736	519	0	538	43,791

[a] Estimated total.

Table 21. Results of sockeye salmon smolt dye experiments in the Russian River, 1993.

Period(s)	Date(s)	Number of Fish Dyed	Number of Dyed Fish Recovered	Trap Efficiency	Calculated Chi Square Value	Table Chi Square Value	Reject Hypothesis? [a]
	5/26	89	1				
	5/28	100	10				
	5/29	100	0				
	6/1	95	1				
	6/2	111	10				
	6/3	110	6				
	6/5	61	5				
	6/6	189	5				
	6/8	44	1				
	6/10	31	2				
	6/27	201	16				
	7/1	363	1				
	7/3	397	7				
	7/4	225	44				
	7/7	250	24				
	7/8	250	31				
	7/10	275	24				
	7/11	258	32				
	7/14	112	23				
	7/15	123	20				
1	5/18–6/2	495	22	0.044			
2	6/3–6/29	636	35	0.055			
3	6/30–7/3	760	8	0.011			
4	7/4–7/7	475	68	0.143			
5	7/8–7/10	525	55	0.105			
6	7/11–7/15	493	75	0.152			
1–6	5/18–7/15				112.29	11.07	yes
1–2	5/18–6/29				0.59	3.84	no
1–3	5/18–7/3				21.33	5.99	yes
3–4	6/30–7/3				76.78	3.84	yes
4–6	7/4–7/15				4.36	5.99	no
1–2	5/18–6/29	1131	57	0.050			
3	6/30–7/3	760	8	0.011			
4–6	7/4–7/15	1493	198	0.133			

[a] Hypothesis: Trap efficiency was independant of dye date; reject at alpha = 0.05.

Table 22. Morphological information collected from sockeye salmon smolt captured in the Russian River, 1993.

Period		1	2	3	4	5
Dates		5/18–5/27	5/28–6/2	6/3–6/23	6/24–6/30	7/1–7/15
N		382	365	331	472	880
Age–0.	N =	0	0	0	0	3
	Percent =	0.0	0.0	0.0	0.0	0.3
Age–1.	N =	122	157	197	458	871
	Percent =	31.9	43.0	59.5	97.0	99.0
Length (mm)	N =	122	157	197	458	871
	Range =	57–92	62–95	65–99	65–98	69–100
	Mean =	83	81	84	80	80
	Variance =	29	39	31	15	14
	Standard Deviation =	5	6	6	4	4
Weight (g)	N =	84	133	189	294	711
	Range =	2.0–6.7	2.3–6.8	2.2–8.7	3.1–10.4	3.8–10.7
	Mean =	4.7	4.5	5.5	5.8	5.8
	Variance =	0.7	0.7	0.9	0.7	0.6
	Standard Deviation =	0.8	0.8	0.9	0.8	0.8
Age–2.	N =	253	208	132	14	6
	Percent =	66.2	57.0	39.9	3.0	0.7
Length (mm)	N =	253	208	132		
	Range =	75–117	78–108	80–130		
	Mean =	97	91	93		
	Variance =	67	36	48		
	Standard Deviation =	8	6	7		
Weight (g)	N =	193	192	123		
	Range =	3.1–12.9	4.2–11.0	3.6–20.1		
	Mean =	7.6	6.4	7.1		
	Variance =	3.0	1.4	3.2		
	Standard Deviation =	1.7	1.2	1.8		
Age–3.	N =	7	0	2	0	0
	Percent =	1.8	0.0	0.6	0.0	0.0

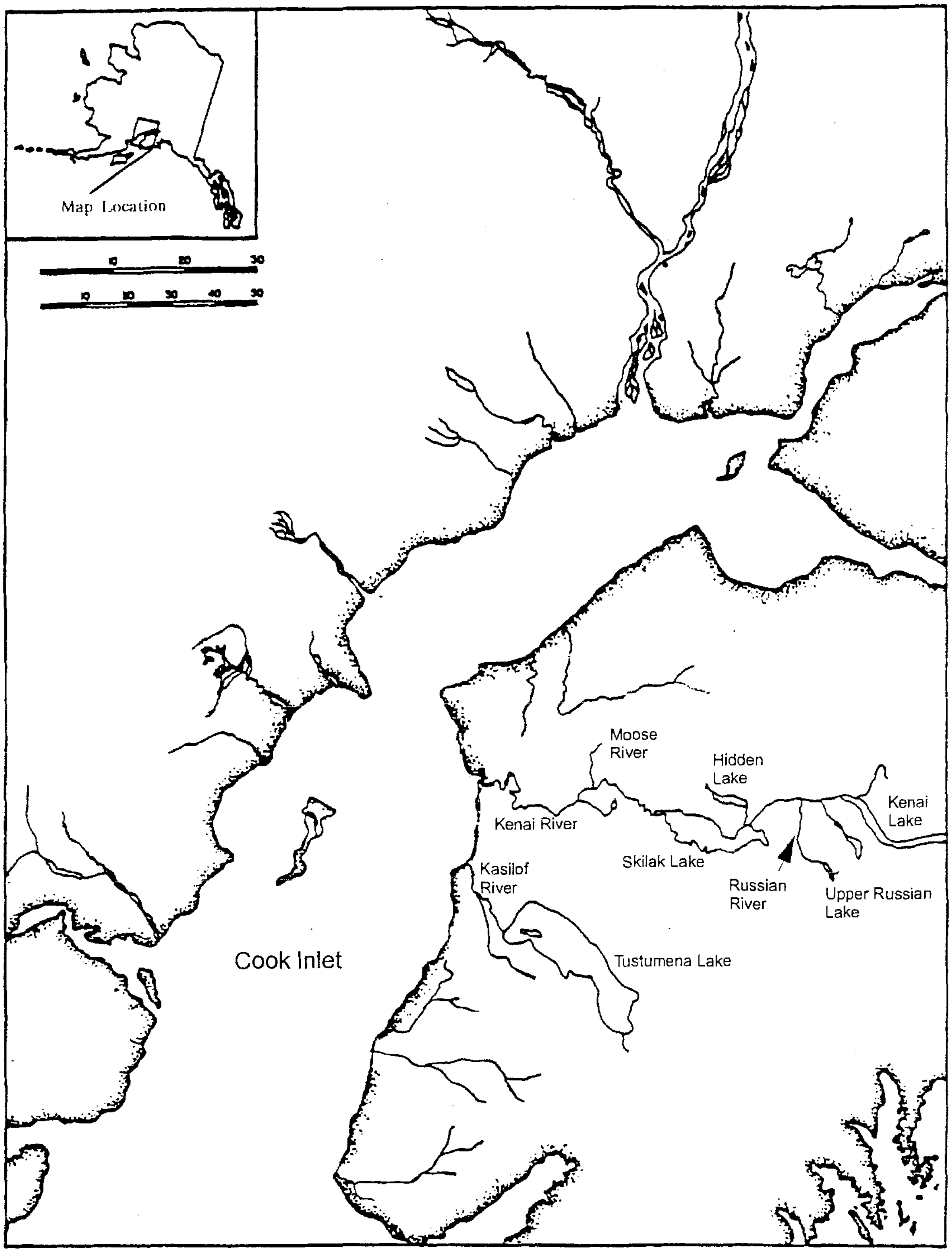


Figure 1. Location of the Kenai River and other noted rivers and lakes in Upper Cook Inlet, Alaska.

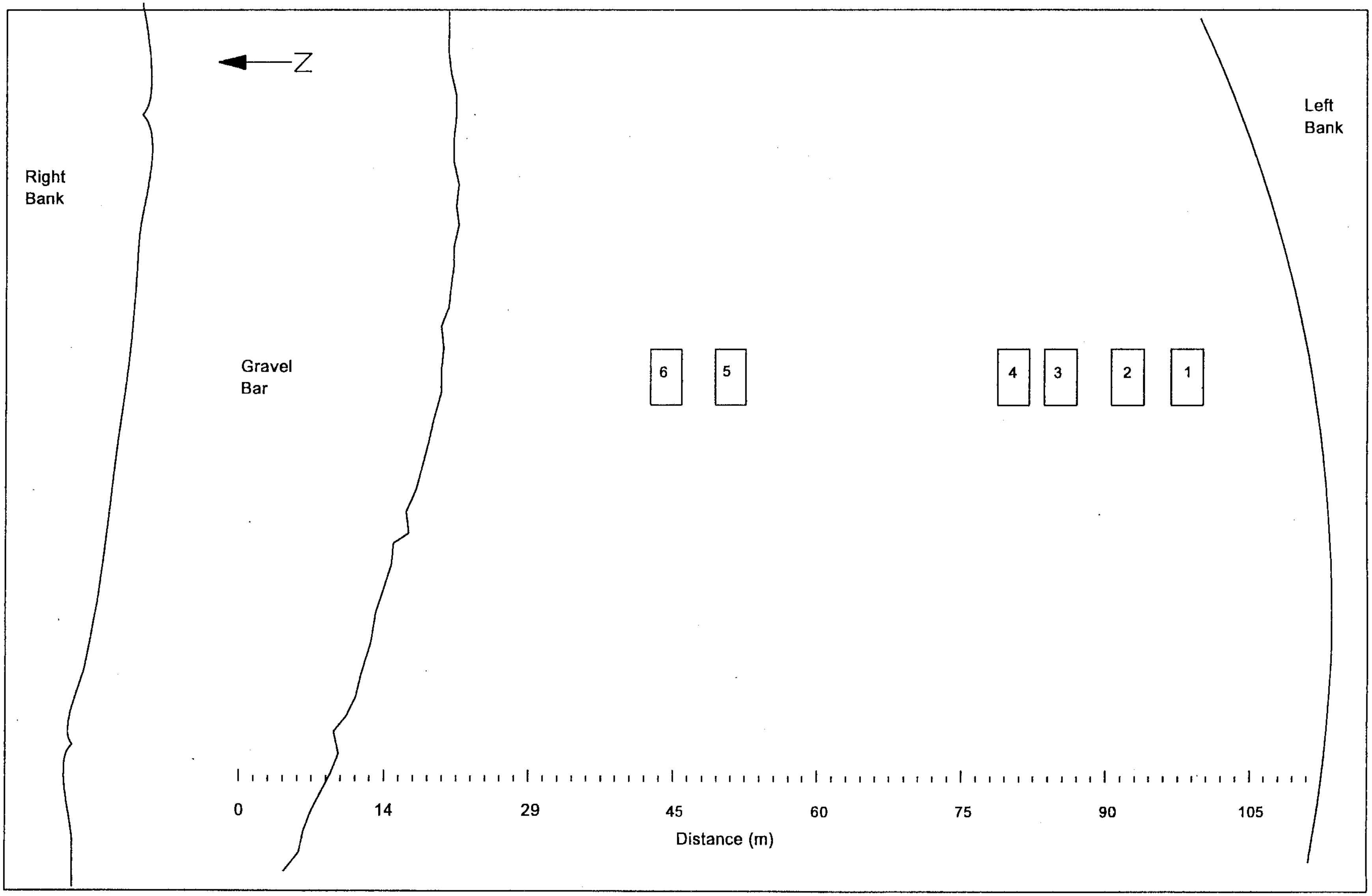
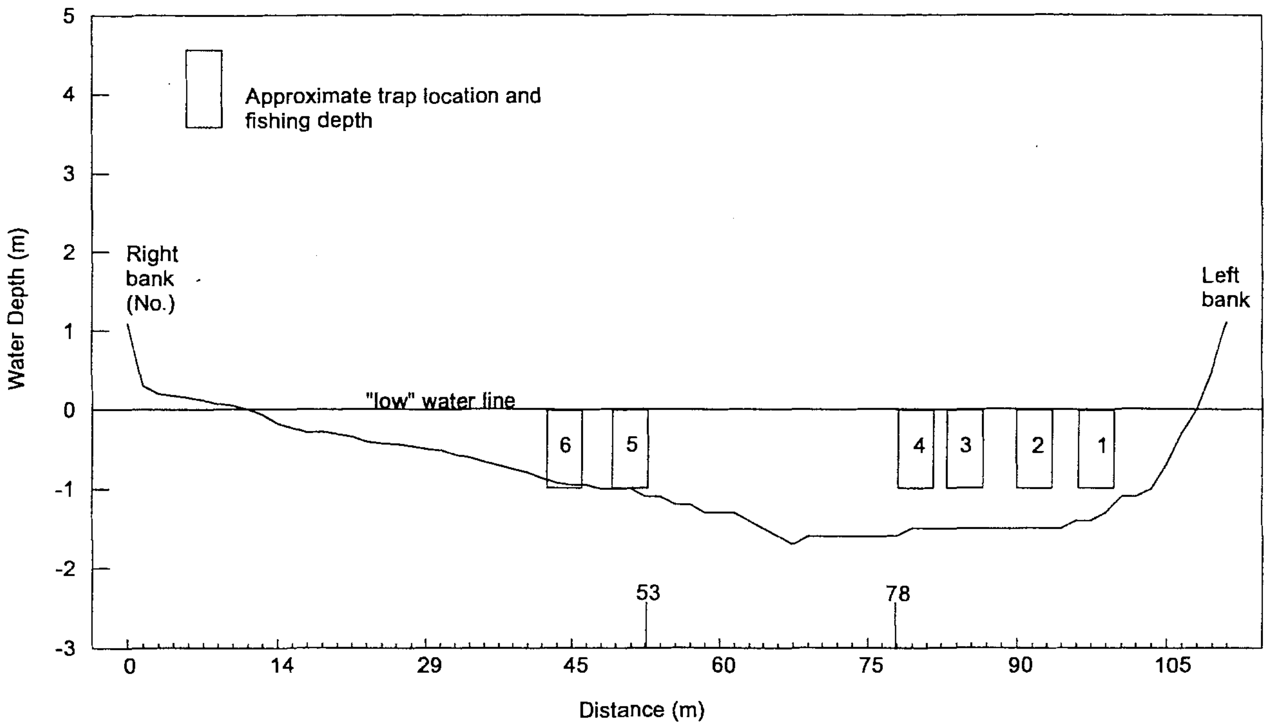


Figure 2. Top view, Kenai River km 31 sockeye salmon smolt enumeration project site.



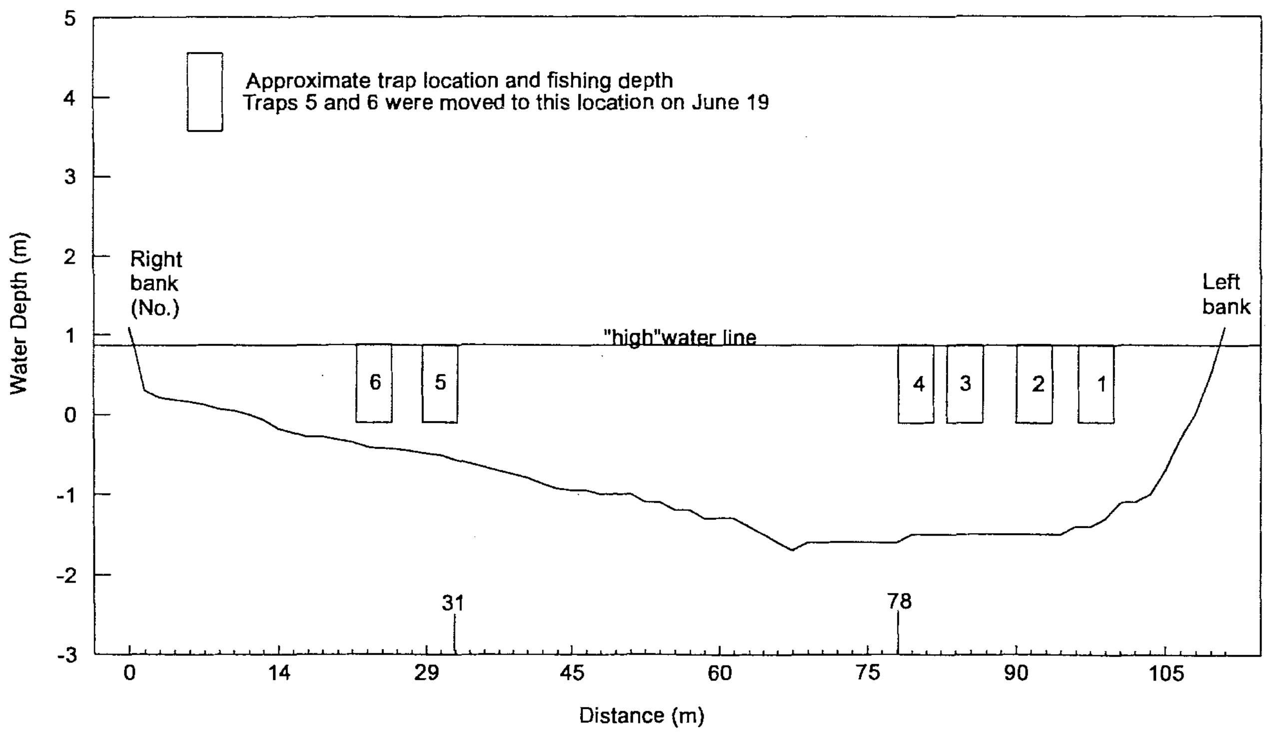


Figure 3. Cross section, Kenai River km 31 sockeye salmon smolt enumeration project site.

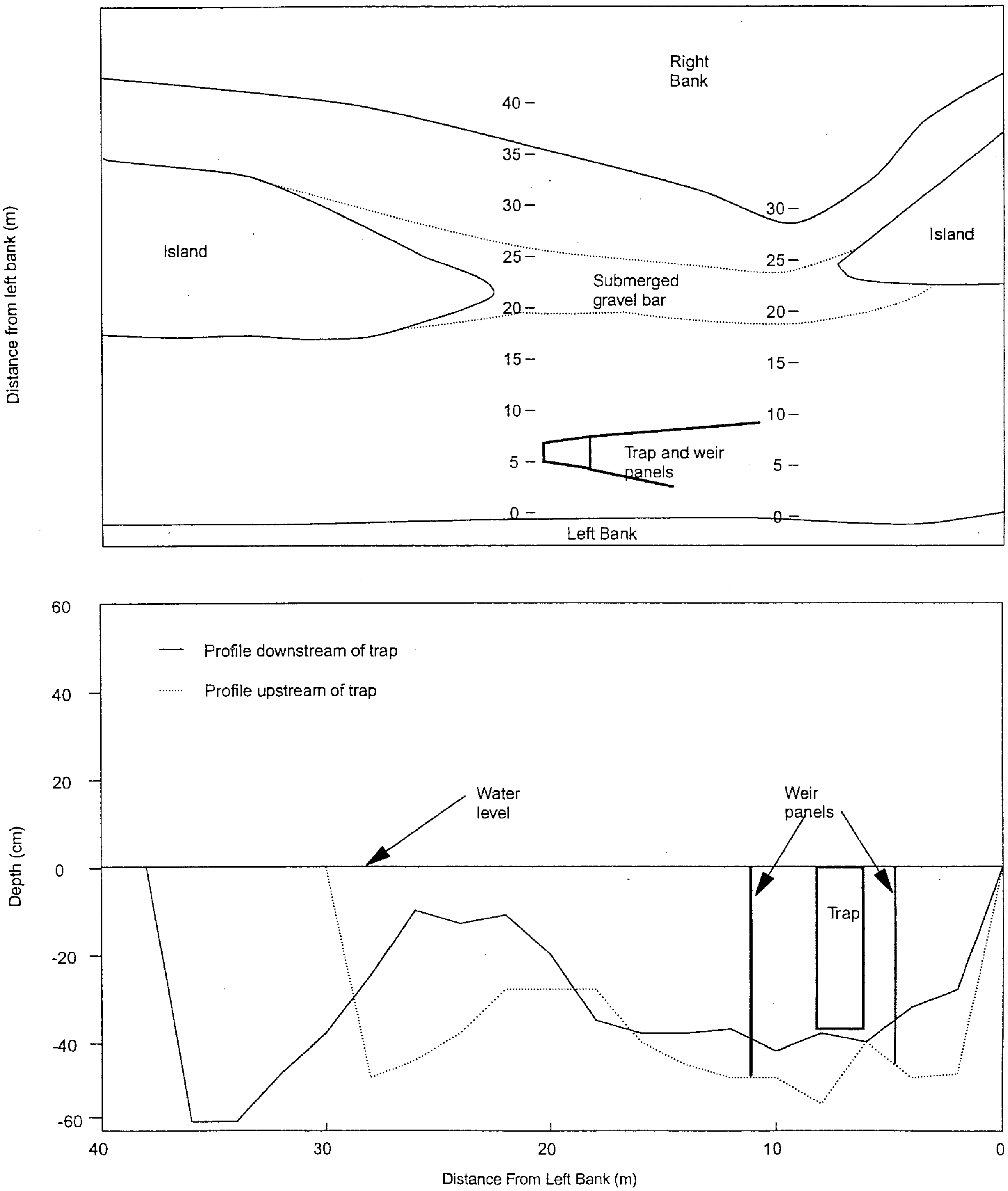


Figure 4. Top view (top) and cross section (bottom) of the Russian River sockeye salmon smolt enumeration site.

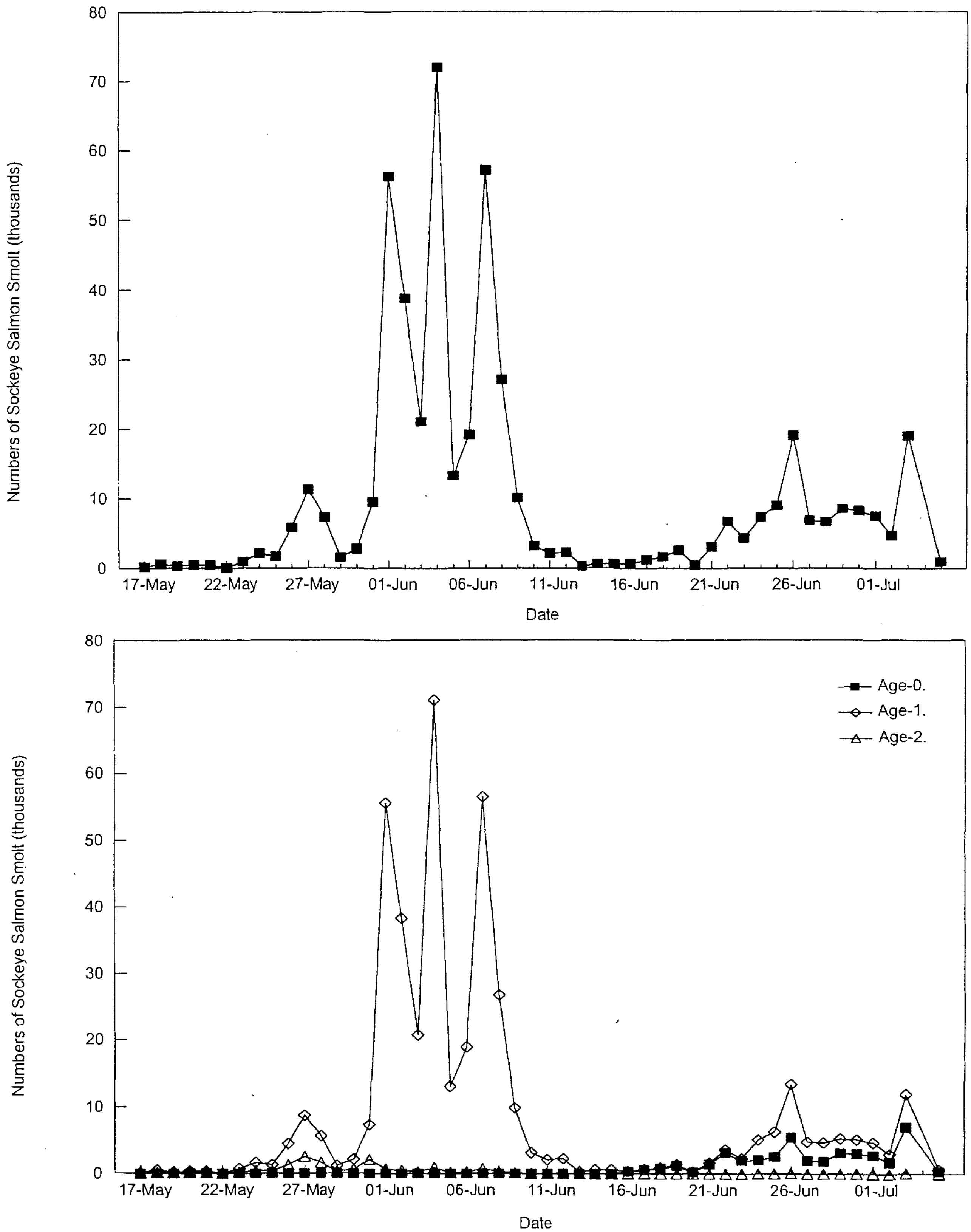
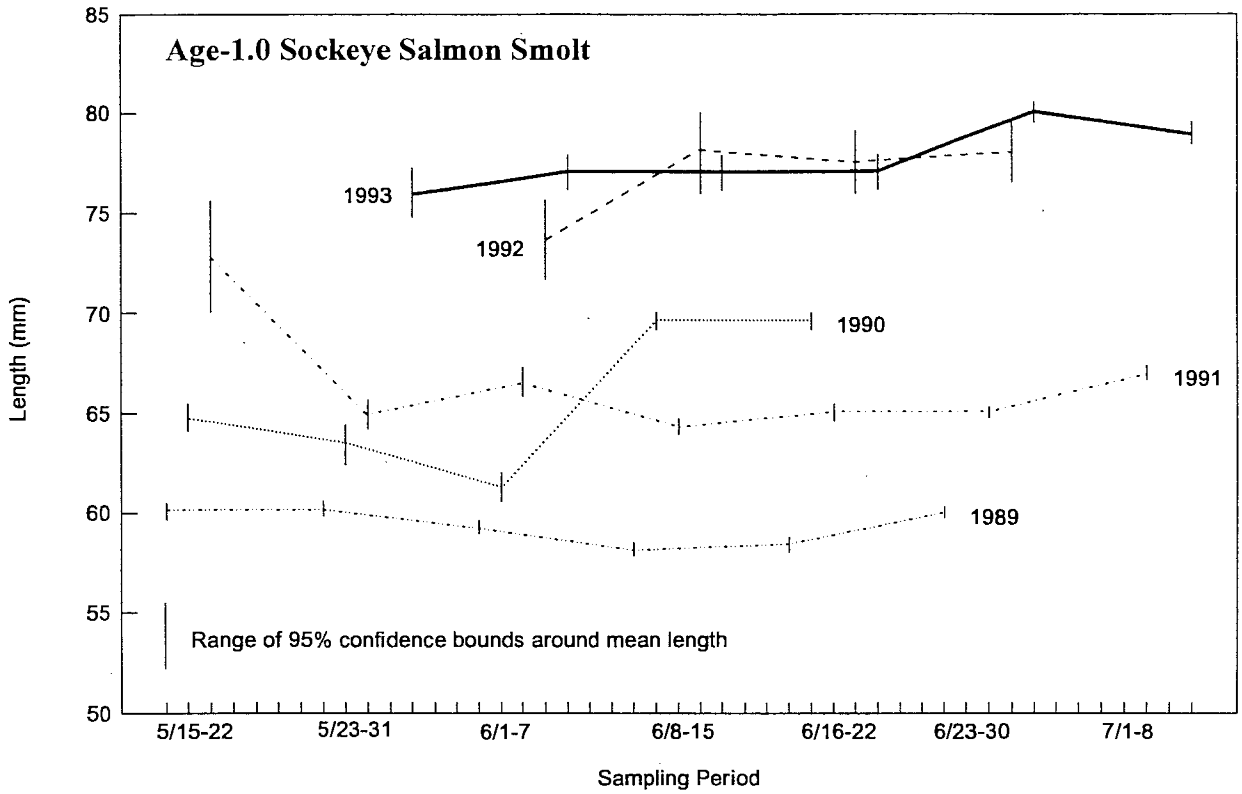


Figure 5. Daily numbers of sockeye salmon smolt, all ages (top) and by age class (bottom), migrating seaward from the Kenai River, 1993.



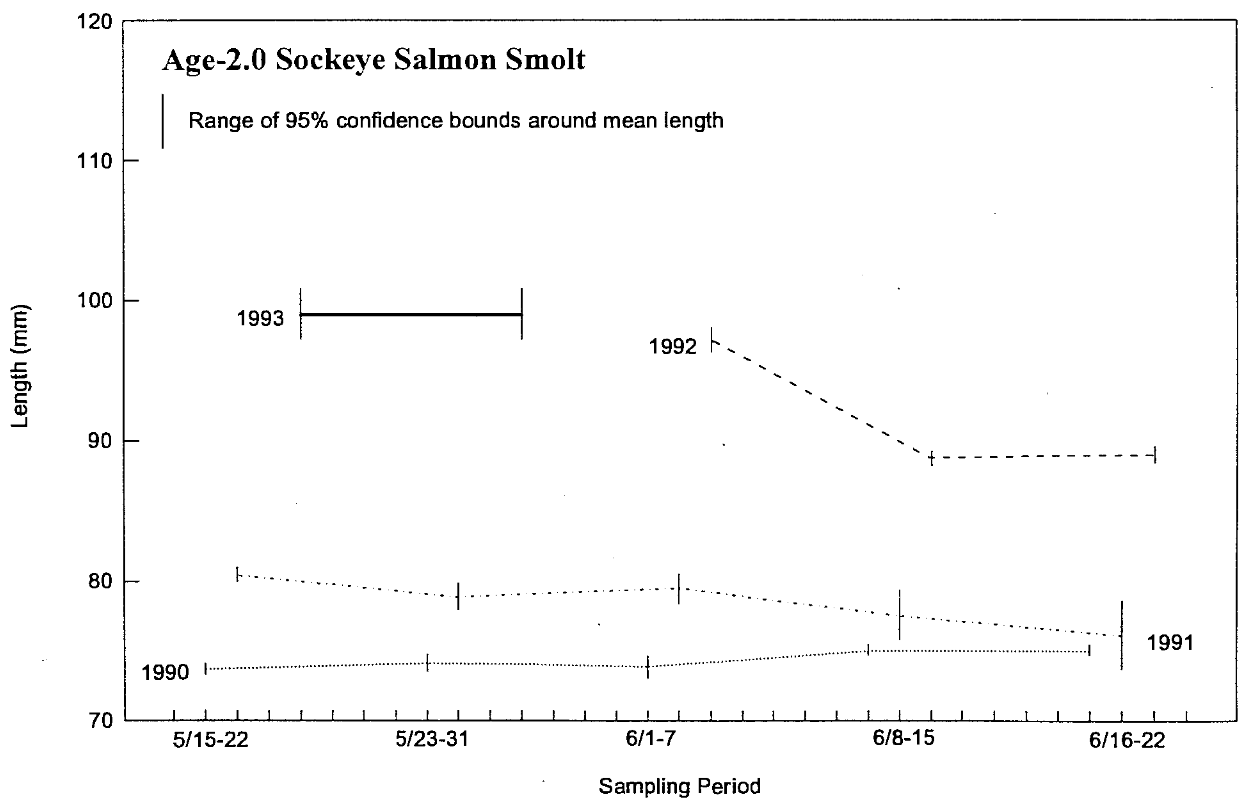


Figure 6. Mean lengths and 95% confidence bounds for age-1. and -2. sockeye salmon sampled at the Kenai River km 31 smolt enumeration site, 1989-1993.

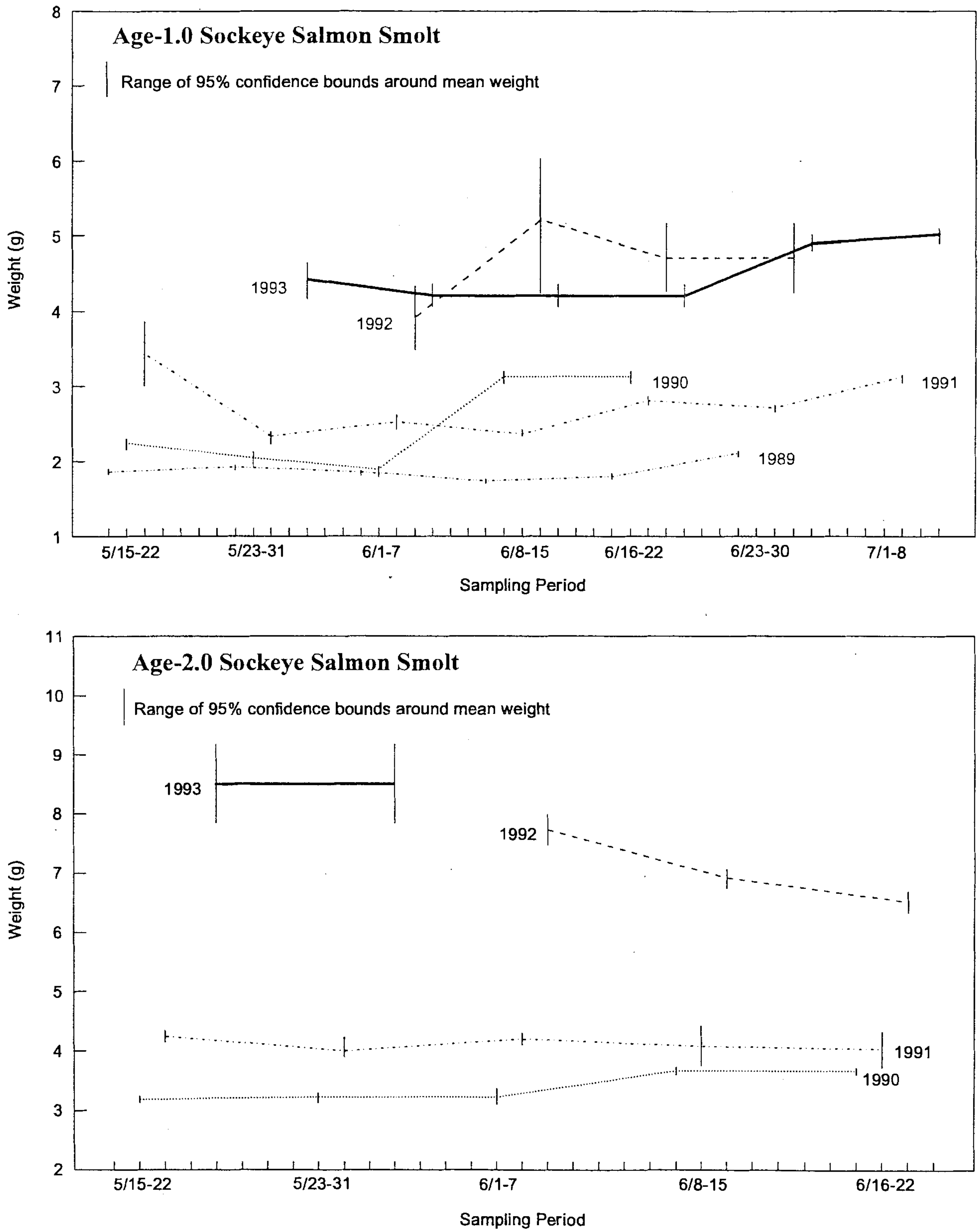


Figure 7. Mean weights and 95% confidence bounds for age-1. and -2. sockeye salmon sampled at the Kenai River km 31 smolt enumeration site, 1989-1993.

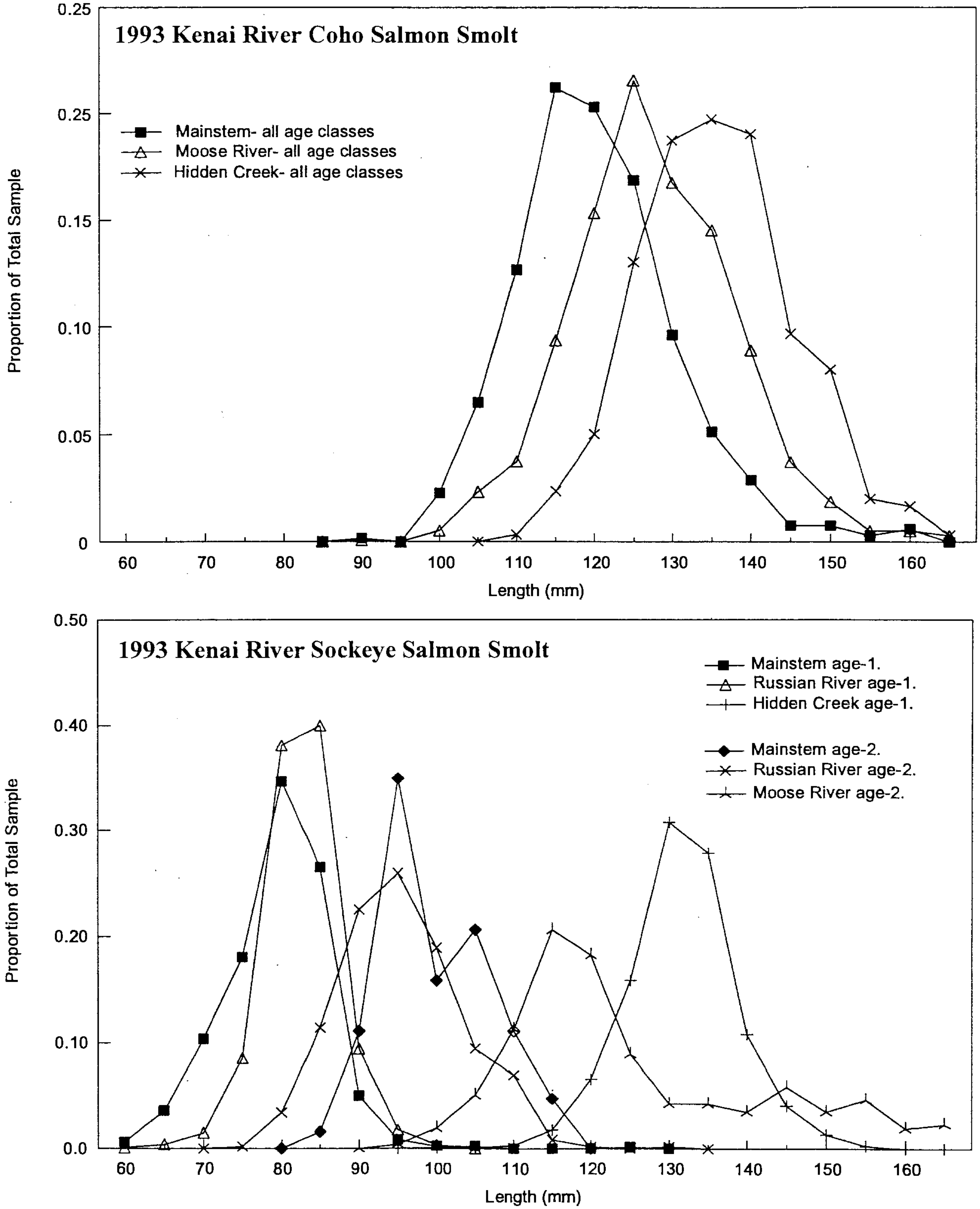


Figure 8. Length frequency distribution of coho salmon smolt (top) and sockeye salmon smolt (bottom) captured in the Kenai River drainage, 1993.

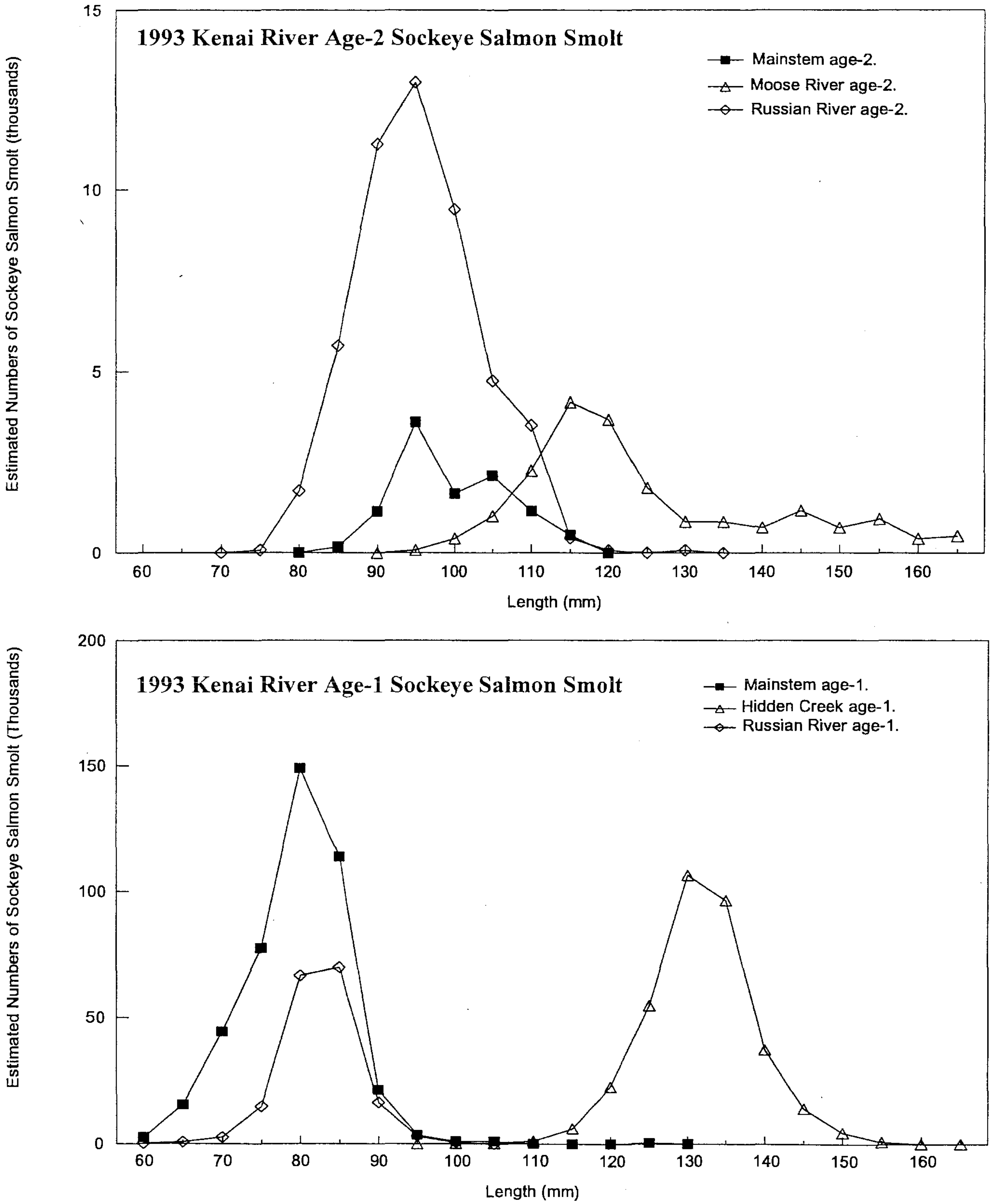


Figure 9. Length frequency distribution of age-1 (bottom) and -2 (top) sockeye salmon smolt from theKenai River drainage, 1993. Estimated numbers of smolt from weirs (Hidden Creek and Moose River), and dye studies (km 31and Russian River).

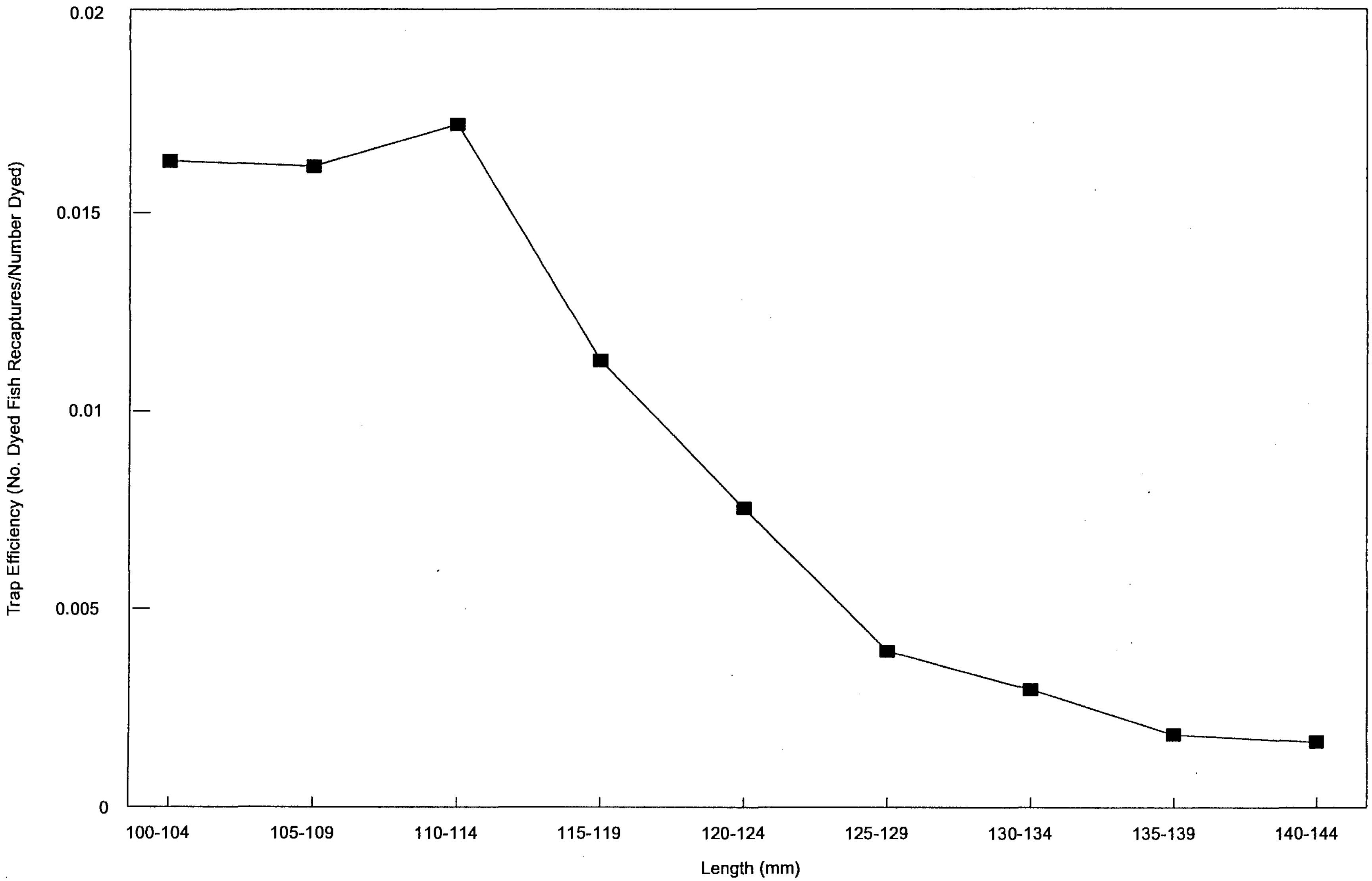


Figure 10. Capture efficiency of km 31 traps for different length coho salmon smolt from the Moose River, 1993.

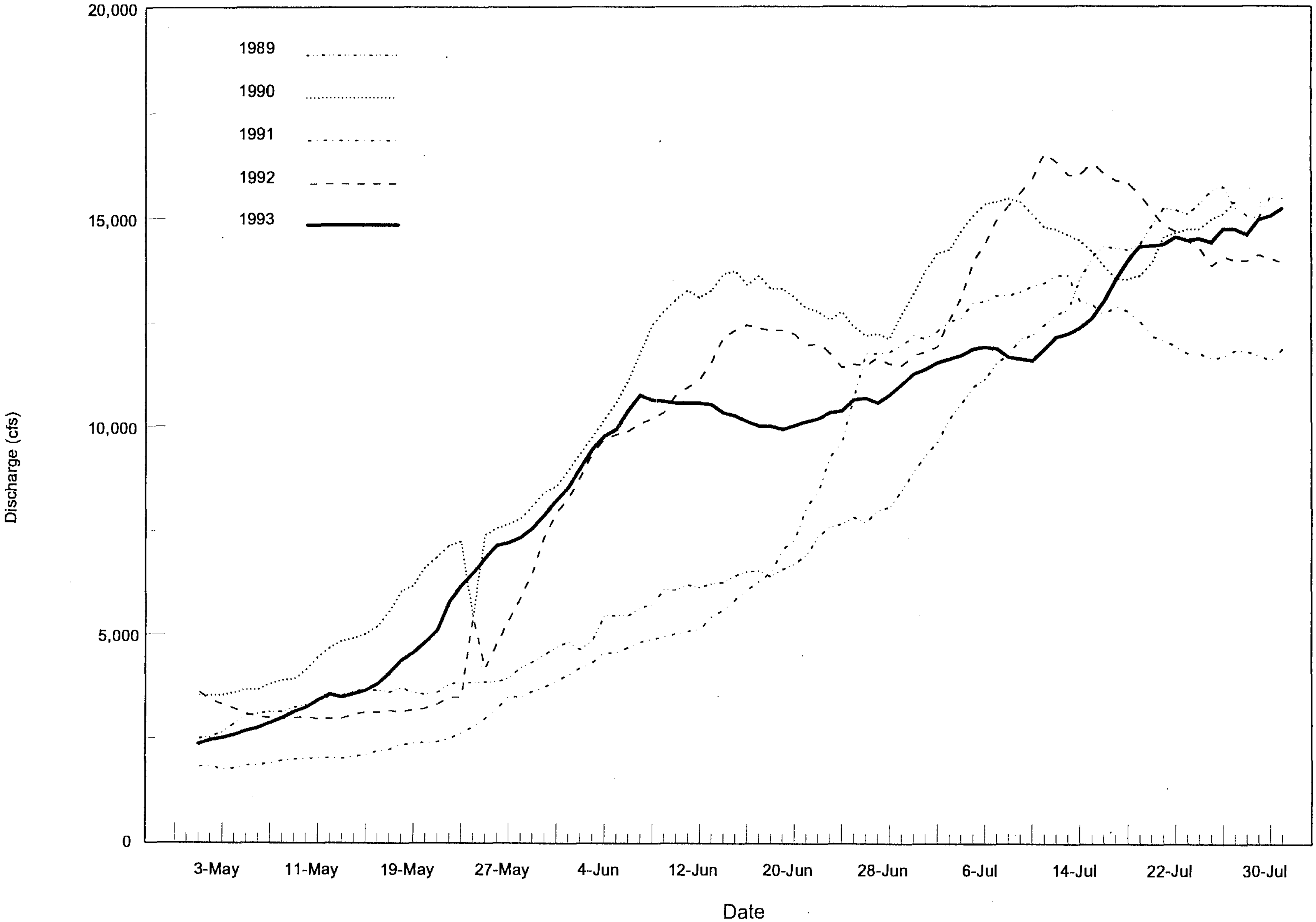


Figure 11. Daily Kenai River discharge, 1989-1993.

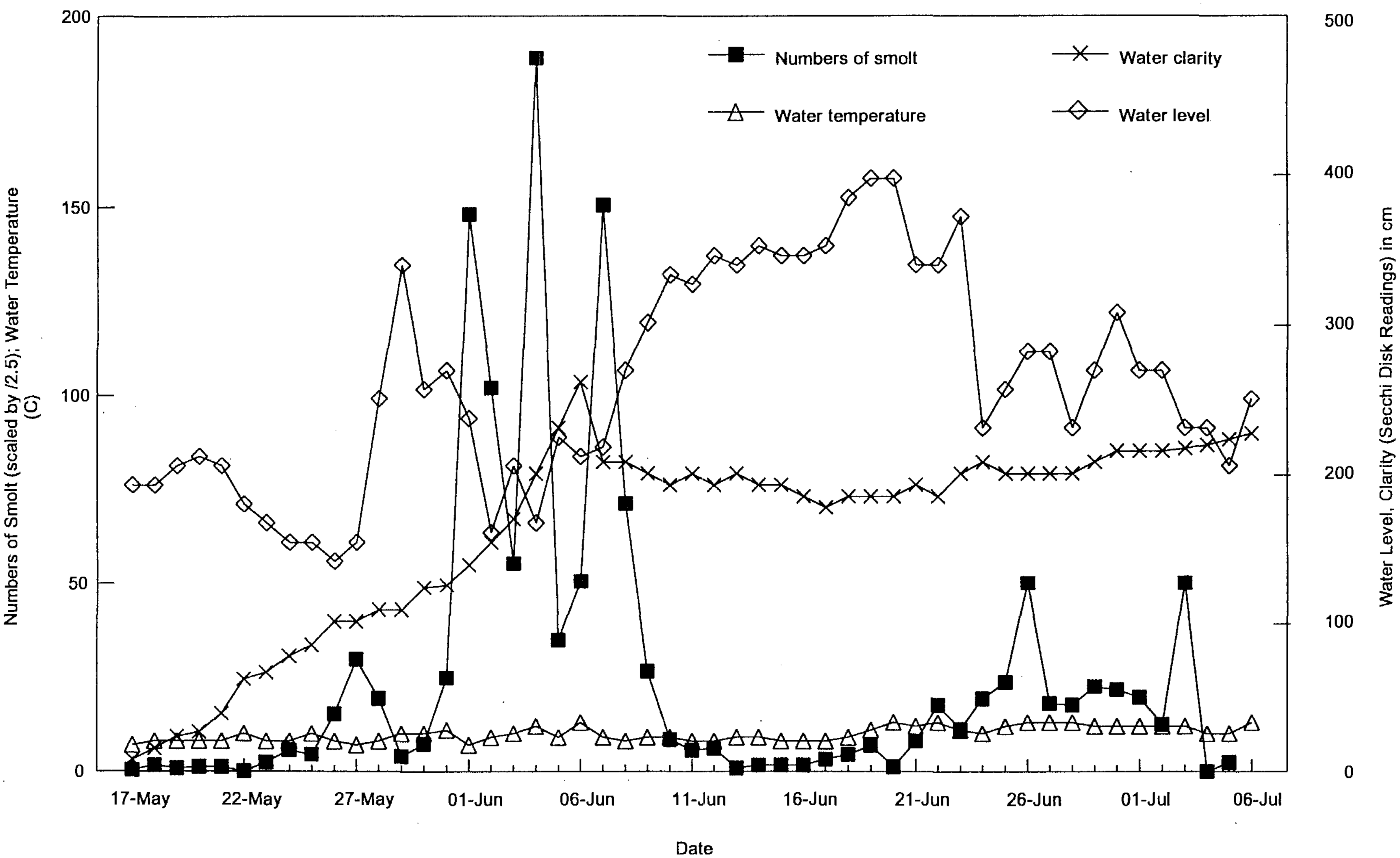


Figure 12. Daily physical parameters measured, and numbers of sockeye salmon smolt captured in the Kenai River, 1993. Y scales adjusted for graphing purposes.

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